# EPITOME

OF

# A COURSE OF LECTURES

ON

NATURAL AND EXPERIMENTAL

# PHILOSOPHY,

AND

# *ASTRONOMY;*

AS DELIVERED BY THE LATE

MR. JOHN BANKS,

*IN ALL PARTS OF THE KINGDOM;*

And as they continue to be delivered annually in Liverpool

BY HIS SON.

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BY THE WORD OF THE LORD WERE THE HEAVENS MADE; AND ALL THE HOST OF THEM BY THE BREATH OF HIS MOUTH. PSALM XXXIII, 6.

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## *Preface to this Edition.*

HAVING met with the moſt liberal ſupport and encouragement in conducting theſe lectures for three ſucceſſive ſeaſons in Liverpool, I cannot do leſs than comply with the numerous requeſts which have been made for the republication of this Epitome, ſince it has been out of print.

In doing this, I avail myſelf of the opportunity of making ſeveral additions to it, in conformity with the intention which my father intimated to me, that he would have made, had he lived to reprint it himſelf.

The progreſſive increaſe in the knowledge of different branches of philoſophy had rendered this neceſſary; and though future diſcoveries may either confirm or correct our views and preſent ſyſtems, yet it is intereſting to obtain a competent acquaintance with the reſults of the inveſtigations of the eminent men in the preſent day, whoſe labours have been devoted to theſe ſubjects.

In contributing my exertions to this end, I acknowledge with pleafure and gratitude the kind partiality of our numerous friends, who have countenanced the eftablifhment of an annual courfe of lectures in this place.

In prefenting this edition to the public, I regret that the increafe in the price of paper and printing, exclufive of the additional matter, impofes the neceffity of charging it higher than the former.

*Jonathan Banks.*

Liverpool, 1809.

## *Preface to the former Edition.*

THIS Epitome is chiefly defigned for the ufe of thofe who have attended my courfe of experiments; to fuch, I am perfuaded, it will be of fervice, by recalling ideas which had flipt the memory; and the want of plates, it is prefumed, will be abundantly compenfated by the apparatus; and to thofe who have not yet had the opportunity, it may, in fome meafure, convey the firft principles of the fciences, provided they will be content with naked affertions, without either mathematical demonftration, or experimental proof.

EPITOME

# EPITOME

OF A

## *COURSE OF LECTURES.*

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### INTRODUCTION.

THIS courſe is intended to explain, in the moſt eaſy and familiar manner, the general properties and laws of matter; and to ſet before the inquiſitive mind, the cauſes of the moſt material phenomena which we obſerve amongſt natural bodies; at lea ſo far as diſcovered: for though we muſt confeſs that the works of infinite wiſdom can never be fully comprehended by the faculties of man, yet how far reaſon, when aſſiſted with inſtruments, may attain, ſeems to us indeterminable; thus the philoſophers of the preſent age, though ſtill wholly ignorant of the true cauſes of many of the moſt common phenomena, have, nevertheleſs, by diligent enquiries and experiments, gained the knowledge of many

 equally

equally unknown to our forefathers, and by them, perhaps, deemed incomprehenſible. And there is no doubt, but, in future ages, ſcience will continue its progreſſion; for it ſeems providentially appointed, as ſome way neceſſary for the carrying on, or well being of ſociety, that the ſciences ſhould be gradually improving. Yet ſtill it muſt be acknowledged, that many things are known, which reaſon could never have led us to the knowledge of; but whilſt man has been diligently ſeeking after one thing, he has accidentally, or rather providentially, hit upon, or diſcovered another, of greater importance, and of more extenſive utility to mankind.

As to the uſe of philoſophy, it muſt be confeſſed to be almoſt unlimited, and may be recommended to people of all ranks. For many things appear to be, what in reality they are not. Thus, to the eye, unaſſiſted by philoſophy, the Sun appears to be a flat ſhining plate, the ſtars to be ſmall lucid points, like diamonds, and all at equal diſtances from us; and ſeem to revolve round the earth in twenty-four hours; while the earth ſeems to be fixed, and to be by much the largeſt body in the univerſe. But a competent knowledge in philoſophy will ſtrip things of the diſguiſe and falſe colours under which they appear; or rather inſtead, as is too commonly ſuppoſed, of contradicting the plain and poſitive proof of the ſenſes, evince, to the moſt unanſwerable demonſtration, the impoſſibility of their appearing otherwiſe;

otherwife ; and from thofe very appearances deduce the moft convincing arguments to fupport its own affertions ; thus will it furnifh the mind with more juft and fublime ideas, by removing the errors of prejudice, received by falfe education, cuftom, or the authority of men.

Philofophy alfo, as it is concerned in the invention and adjuftment of machines, is of univerfal utility to mankind ; to it we owe the conftruction of fhips, fteam-engines, water-engines, pumps, mills, clocks, watches, dials, telefcopes, cranes, jacks, the organ, harpfichord, and every other kind of inftrument, machine, or engine, however complicated, or for whatever purpofes they are appointed.

In teaching philofophy as a fcience, it is neceffary to begin with the moft fimple and known properties of bodies ; and thence to proceed, by inferring one truth from another, till we arrive at the moft abftrufe parts ; always ufing experiments where the nature of the thing will admit them, except that which is afferted be fufficiently plain without. And though the experiments afford the higheft degree of entertainment to the rational mind ; yet fo much the more inftruction will they convey, as this regular procefs is moie attended to, and better imprinted on the memory.

LECTURE

## LECTURE I.

### THE GENERAL PROPERTIES OF MATTER.

THIS Lecture is intended to explain the general properties of matter, the different kinds of attraction, and from thence to deduce the principles of feveral ufeful arts. We have four rules whereby we fhould be guided in our philofophical enquiries; the firft is,

*That more caufes for natural effects are not to be admitted than are both true and fufficient to explain the phenomena.*

This agrees with reafon, and revelation; for it is certain that God has made nothing in vain; which would evidently be the cafe, if two caufes were admitted where one would ferve.

The fecond is, *That for natural effects of the fame kind, the fame caufes are to be affigned, as far as can be done.*

That is, we are to affign the fame caufe for the falling of ftones in America, Africa, &c as in Europe; the fame caufe for refpiration in man and beaft; and that light in all kinds of bodies is produced by the very fame caufe.

The

The third rule is, *That the qualities of natural bodies, which cannot be increaſed or diminiſhed, and agree to all bodies on which experiments can be made, are to be reckoned, as the qualities of all bodies whatſoever.*

Thus, becauſe extenſion, ſolidity, diviſibility, &c. are found in all bodies that we know, we may juſtly conclude that they belong to all bodies whatſoever.

The fourth rule is, *That in experimental philoſophy, propoſitions collected from the phenomena, by induction, are to be deemed, notwithſtanding contrary hypotheſes, either exactly or very nearly true, till other phenomena occur, by which they may be rendered either more accurate, or liable to exception.*

All bodies whatever are found to have the following common properties, viz.

| | |
|---|---|
| *Extenſion,* | *Mobility,* |
| *Solidity,* | *Vis Inertiæ,* |
| *Diviſibility,* | *Attraction and Repulſion.* |

*EXTENSION,* is a property which belongs to all matter in general; for it is certain no body can exiſt, but it muſt take up ſome part of ſpace.

*SOLIDITY,* is that property which a body hath of excluding all others from the place it poſſeſſes.

*DIVISIBILITY,*

*DIVISIBILITY*, is a property whereby bodies are capable of having their parts feparated *ad infinitum**. That this property exceeds the utmoft bounds of our imagination, is a mathematical truth, and may be demonftrated different ways.

*MOBILITY*, is that property which bodies have of being moveable.

The *VIS INERTIÆ*, or inactivity of matter, is that property whereby bodies refift the action of other bodies, tending to generate or deftroy motion in them.

*ATTRACTION*, is a property whereby bodies mutually tend towards each other: if the bodies be of unequal magnitude; in the greater, it is called attraction, and in the leffer, gravitation.

*REPULSION*, feems to be a property belonging to the fmalleft particles of matter: thus we fee the particles

*If it is true, as generally maintained, that one particle is capable of being divided into an infinite number, which number cannot be increafed; may not another particle alfo be divided into an infinite number, which number cannot be increafed; and in like manner a third, &c. and if thefe cannot be added, will it not follow that there may exift many infinite numbers?

But if the whole material creation, however extenfive, was divided into particles infinitely fmall, would the number be more than infinite.

particles of water, ſeparated by the action of fire, repel each other; and the particles of any kind of hard matter, being ſet at liberty by ſome chemical proceſs, conſtitute a perfectly elaſtic air.

The attraction of gravitation takes place only in large bodies, ſuch as the Sun, Earth, and planets, and is a property whereby all ſmaller bodies within the ſphere of their attraction, tend towards their centres. The attracting effluvium or energy is found to decreaſe as the ſquares of the diſtances increaſe; that is, if a body at the diſtance of 10,000 miles from the earth, tend towards it with a certain force; at the diſtance of 20,000 miles, it would tend towards it with only one fourth part of that force; at the diſtance of 30,000. with only one ninth part thereof, &c.

The planets are all retained in their orbits by the attraction of the Sun; and by their motions, the above law is fully confirmed; for as the ſquare of the diſtance of Venus from the Sun, is to the diſtance that Mercury falls from a tangent to his orbit in one hour; ſo is the ſquare of the diſtance of Mercury from the Sun, to the diſtance that Venus falls from a tangent to her orbit, in the ſame time; *and ſo of the reſt.*

The power which unites the original particles is called the attraction of coheſion, and is mutual between them, or they are attracted and attract each other.

other. This power ſeems to act only in contact, or at imperceptible diſtances in all ſolid bodies. The exiſtence of this power is proved by two leaden balls, having their ſurfaces pared very clean, and preſſed together with a gentle twiſt, after which they will require 40, 60, or 100 pounds weight to pull them aſunder, according as more or leſs of the ſurfaces are in contact: for this power ſeems to act nearly in proportion to the quantities of contiguous ſurfaces. This is the natural cement by which the parts of ſolid bodies are bound together, and by which they are kept from crumbling to their original duſt. Hard bodies, which cannot by preſſure be brought into intimate contact like the leaden balls, require ſome kind of matter to be put between them, in order to make them cohere; ſo if flint, glaſs, &c. reduced to impalpable powder, and mixed with ſome viſcid fluid, be applied between two bodies, whoſe ſurfaces are clean, when dry it will make them cohere very firmly. Hence we ſee the reaſon that in poliſhed ſurfaces, a little damp is ſufficient to make them cohere; if a little oil or tallow be uſed, the coheſion is much ſtronger, *as is ſhewn by experiment.*

From this principle we have alſo the nature of ſoldering, gluing, foliating glaſs, ſilvering and gilding metals, &c. *as explained in the lecture.*

The attraction of coheſion is different between the particles of different bodies; thus, water put into

into clean glaſs, china, &c. is ſeen to riſe all round by the ſide of the veſſel; but if quickſilver be uſed, it will ſtand loweſt at the ſides; from whence it appears, that the power of attraction is greater between the glaſs and water, than among the particles of water themſelves; and that it is greater among the particles of quickſilver, than between the glaſs and quickſilver. In this ſimple cauſe, divine wiſdom is abundantly manifeſt; for by it we have numbers of the moſt extraordinary effects produced.

It is owing to this, that water riſes above the common level in the capillary tube; alſo the action of the capillary ſyphon, and filtre, depends on the ſame principle; for the capillary ſyphon, being a ſmall bended tube of glaſs, by attraction raiſes water up one leg, carries it over the bended part, and down the other, where it falls, by its own weight, drop by drop. The filtre being made of yarn, felt, cloth, &c. the filaments act like ſo many ſyphons, and carry a fluid off in the ſame manner, but much faſter. From hence we have the reaſon of fluids riſing in heaps of ſand, aſhes, ſugar, &c; of tallow riſing in the wicks of candles; of water being drawn up the ſpunge; of ink riſing in the pen, and alſo of its being drawn out again in writing. From hence we alſo account for the riſing of ſap in trees and plants; for, upon proper examination, it is found that the bodies of trees are compoſed of an infinite number of capillary tubes, of different magnitudes;

 the

the largeſt ſeem, by various experiments, to be appointed for the circulation of air; and the ſmaller for attracting the juices of the earth, and raiſing them to the top and utmoſt parts of the branches: for it may be obſerved, that the ſmaller the bore of the tube, the higher a fluid will riſe, *as is ſhewn in the experiment.*

The tendency which different ſubſtances have to unite together in a chemical way, has generally been attributed to different degrees of attraction exiſting amongſt their conſtituent parts; and as in many caſes the effects produced are proof of a very ſtrong diſpoſition to union, or combination, this has ſometimes been diſtinguiſhed by the term *affinity*, or *elective attraction.* This affinity is known, by repeated experiments, to be always the ſame betwixt the ſame ſubſtances: and from the various degrees of it ſubſiſting betwixt any one ſubſtance, and any number of others, tables of affinity have been compoſed, by which may be ſeen its various gradations. Upon this principle of one ſubſtance having a ſuperior attraction to ſome one other, a weaker degree of attraction to a ſecond, ſtill leſs to a third, &c. depends the analyſis of all compound bodies, as well as their original compoſition. Hence we perceive the cauſe of

*Solution.*

As it is neceſſary, in order to effect the union of two

two ſubſtances, that one of them be in a liquid ſtate, if a ſolid and a fluid be put together, provided the power of attraction between the particles of the fluid and the particles of the ſolid be ſtronger than between the particles of the ſolid themſelves, every particle of the fluid will then attract a particle of the ſolid, or ſo many of them as it can ſuſtain, and then the whole menſtruum being ſaturated therewith, the ſolution will ceaſe.

This may be illuſtrated by putting ſalt or ſugar in water, which will diſſolve a conſiderable proportion of theſe ſubſtances, and hold them in ſolution, yet remain as tranſparent as before.

If the liquid be heated, and as much ſalt added as it can diſſolve; upon cooling again it will let go a part of the ſalt, by which it appears that heat aſſiſts ſolution, or renders the menſtruum capable of holding more of a ſubſtance in ſolution, than it will do at a lower degree of temperature.

Solution is alſo exemplified in the conſtant action of the air upon water, which is diſſolved and diffuſed through the whole atmoſphere, and exiſts in it, in a ſtate of ſolution, when the air is moſt tranſparent.

Solution, in a more compound way, may be illuſtrated by putting ſilver, copper, braſs, iron, &c. in

nitric acid (aqua-fortis) but in this procefs, befides the folution of the metal, a partial decompofition of acid takes place; the metal will however be diffolved and difperfed through the acid, by which it will be fuftained, and that without deftroying its tranfparency.

Solution differs therefore from mixture; for any finely powdered fubftance may be, by agitation, difperfed through a liquid, and fufpended in it for a time; but if it be not capable of folution in the liquid, it renders it opake, and will fhortly fall down to the bottom, having undergone no change.

*Precipitation*

Depends alfo upon the fame principles. If to any kind of folution fome fubftance be added, fo fhall there be a ftronger attraction between the new added matter and the menftruum, than between the menftruum and the diffolved body, the new matter will then take place of the old, and let it fall to the bottom.

To a folution of Epfom falt, add a folution of alkali, and the bafis of the Epfom falt will be precipitated in white flakes, which is the *magnefia alba.*

Epfom falt is compofed of magnefia and the acid of vitriol, or fulphuric acid; it is therefore denominated fulphate of magnefia.

A more

A more powerful attraction takes place between the acid and the alkali, than between the acid and magnefia; hence the magnefia is thrown down, and the union of the acid and the alkali conftitute a different kind of falt, the fulphate of pot-afh (vitriolated tartar.)

The effects of this affinity in different fubftances is of the greateft ufe in difcovering the ingredients contained in any tranfparent liquid; for frequently fubftances of a pernicious tendency are held in folution in water, &c. and by the addition of a proper teft, may be difcovered either by precipitation, or change in the colour.

Thus lead is difcovered in water or white wine, by adding fulphuret of pot-afh (liver of fulphur) diffolved in lime water: the mixture appears red, and in time precipitates.

Copper in folution may be difcovered by the addition of volatile alkali.

Iron will alfo precipitate copper, if the folution be moderately ftrong; the acid, preferring the iron, diffolves it, and the copper is precipitated on its furface.

Iron, held in folution, may be difcovered by a

 decoction

decoction of galls, which turns the solution black; or it may be precipitated by pruſſiat of pot-aſh (phlogiſticated alkali) and if muriatic acid be added, a beautiful Berlin blue is formed.

Water containing ſelenites, allum, ſal-ammoniac, or calcareous earth, will appear milky by adding a ſolution of pot-aſh.

New ſyrup of violets added to water which contains an acid, will turn it red, but if it contains an alkali, green.

A further variation takes place in thus chemically combining different ſubſtances; for two ſubſtances, which ſeparately emit very ſtrong effluvia, when united form a compound which is without ſmell, and the contrary.

Muriatic acid and ammonia combined, conſtitute muriate of ammonia, which has no ſmell.

Quicklime and muriate of ammonia (ſal-ammoniac) pounded very fine, and afterwards mixed together, emit a very ſtrong ſmell.

Alkohol and nitric acid, when mixed, produce a compound, having a very agreeable odour.

By means of this chemical affinity, various ſub-
ſtances

ftances are effentially changed as to their properties in the compound ; and though either of them taken feparately are free from any bad confequences, yet the fame quantity of the compound becomes the ftrongeft of poifons.

Alfo fubftances, which feparately have a corrofive quality, when combined entirely lofe it, and become quite harmlefs.

As fulphuric acid and quicklime, which will either of them burn or corrode, but when combined form plafter of Paris, poffeffing no fuch property.

*Fermentation*

Depends upon the fame principles ; for if two fluids be put together, provided there be a different power of attraction between their particles, they will thereby be thrown into a ftrong agitation and commotion amongft themfelves, and will be fo incorporated with each other, that they will feem to have changed their properties, and acquired new ones : in fact a decompofition of the liquids takes place, and their elementary parts form new affociations, poffeffing properties ftrikingly different to the original ingredients.

The putrefactive fermentation is carried on by the fame means, but the combinations formed, differ ; the

conftituent

conſtituent parts of the ſubſtance eſcaping in the form of gas, and leaving only an earthy reſiduum.

The acetous fermentation takes place under proper circumſtances from the affinity betwixt wine and the oxygen of the atmoſphere, and may be forwarded by communicating oxygen to the wine, &c.

This affinity produces very ſtriking effects in pyrophorus, phoſphorus, oxygenated muriate of pot aſh, and ſulphuric acid, &c.

From this difference of the degrees of attraction between different bodies, we have perhaps the moſt rational manner of accounting for heat, exploſions, earthquakes, volcanos, &c.

If aqua fortis be poured upon iron filings, a very conſiderable degree of heat will be produced.

Alſo, if three parts of nitre, two of ſalt of tartar, and one of ſulphur, be pounded and mixed together, (which mixture is called *pulvis fulminans*) and a ſmall quantity of it heated upon an iron plate, as ſoon as it begins to melt, and the particles of the different bodies come in contact, the nitre is in an inſtant converted into air.

## MAGNETISM.

The attraction of *magnetiſm* is peculiar to the loadſtone

loadſtone and iron, as there is no other body but iron that it can be communicated to.

Every loadſtone has two poles; one called the north, and the other the ſouth pole.

This virtue may be communicated to iron different ways, and thereby artificial magnets may be made to anſwer all the ends of a natural one.

If we take four or five ſteel bars, ſix inches long, half an inch broad, and about an eighth of an inch thick, well poliſhed and hardened, if they be laid end to end, and the magnet drawn over them ſeveral times, they will become ſtrongly impregnated with the virtue. Theſe properly fitted up in a caſe, will make a good artificial magnet: but perhaps it may be better, in ſome caſes, to have the bars bent in a particular manner, *as is ſhewn in the experiment.*

This virtue may alſo be communicated to a piece of poliſhed ſteel, by placing it in the magnetic meridian, and rubbing it always one way with a burniſher.

Iron bars, by ſtanding long in one poſition, acquire the magnetic virtue.

If a magnet be made red hot, or become ruſty, it loſes much of its virtue.

It is generally ſuppoſed that the effluvia, coming out at one pole, return in curves of various directions, and enter in at the other ; and indeed we have ſeveral experiments which countenance ſuch an hypotheſis.

If a piece of paper be wrapped over the end of a magnet, including the two poles, and the magnet be applied to a few fine iron filings, they will be taken up by it in the form of curves communicating from one pole to the other.

Alſo if three magnetic bars be laid parallel to each other, in ſuch order that the north end of the firſt ſhall correſpond with the ſouth end of the ſecond, and the third be laid with its end in the ſame direction as the ſecond, and afterwards a piece of clean paper covering the whole ; upon duſting fine particles of iron upon the paper they will aſſume curves, which indicate the direction of the magnetic effluvia.

If a magnetic needle be ſuſpended upon a point, in England, it will now make an angle with the meridian about 22 degrees ; the north end being towards the weſt, and the ſouth end towards the eaſt, which is called the variation of the needle.

In 1580, it had one point eaſt variation ; in 1657, it had no variation.

When

When a needle is well made, and fufpended like a fcale beam, in moft places it dips below the plain of the horizon.

In 1775, in a voyage to Madras, the variation and dip were as below.

| Latitude. | | Longitude. | | Variation. | | Dip. | |
|---|---|---|---|---|---|---|---|
| N. 49° | 0′ | W. 9° | 0′ | W. 18° | 42′ | N. 73° | 4′ |
| 33 | 30 | 15 | 30 | 19 | 16 | 65 | 1 |
| 9 | 15 | 16 | 0 | 12 | 50 | 38 | 6 |
| 1 | 10 | 16 | 16 | 12 | 47 | 24 | 2 |
| S. 7 | 10 | 23 | 30 | 6 | 30 | 11 | 0 |
| 14 | 6 | 26 | 28 | 4 | 20 | S. 2 | 2 |
| 22 | 8 | 31 | 0 | E. 0 | 44 | 15 | 3 |
| 34 | 25 | 18 | 21 | W. 3 | 18 | 35 | 6 |
| 34 | 49 | E. 36 | 26 | 27 | 30 | 58 | 4 |
| 28 | 20 | 78 | 10 | 12 | 49 | 57 | 7 |
| 5 | 26 | 81 | 17 | 0 | 8 | 30 | 3 |
| N. 5 | 19 | 88 | 13 | 0 | 53 | 8 | 0 |
| 9 | 28 | 85 | 10 | 0 | 53 | N. 0 | 5 |
| 10 | 55 | 84 | 55 | 0 | 53 | S. 0 | 33 |
| 14 | 17 | 81 | 23 | 1 | 22 | 8 | 5 |

LECTURES II. & III.

# PNEUMATICS.

Pneumatics is that part of philofophy which treats of the nature and properties of the air.

The particles of air are extremely fmall, fo that they evade the fight, though affifted with the beft glaffes. It is moft likely that thefe particles are round, and that a repelling power takes place between them; for the air is found to be an elaftic fluid.

The whole body of air in which we breathe, and which furrounds the globe of the earth, is called the atmofphere.

The air, being elaftic, is at every different altitude of a different denfity; that is, it is moft denfe upon the furface of the earth, and the higher we afcend, it becomes more rare or thin; except that which is near the earth be fometimes rarified by the heat reflected from its furface.

The altitude of the atmofphere is not exactly known; it extends about 45 miles above the earth's furface before it be too thin to refract a ray of light; if

if it was every where of the ſame denſity with that near the earth, its altitude would be about five miles and a quarter.

That the air is a body, is evident, by its excluding other bodies from the place it poſſeſſes; for if a glaſs be inverted and ſunk in water, the water will not riſe in it, as is evident by a lighted candle continuing to burn in it, though under water. The diving bell depends on this property of the air; for if a large veſſel be made heavy enough to ſink with the open end downward, a perſon may deſcend in it to a conſiderable depth, and the water will be kept from riſing, by the ſpring of the air: yet the air being elaſtic, and therefore capable of being compreſſed, as the bell deſcends the water will gradually riſe; and when it comes to the depth of 33 feet, half its capacity will be filled with water; but it may be kept from riſing, or driven out after it is riſen, by ſending down caſks filled with freſh air, which may be taken in at the bottom of the bell, while that corrupted by breathing may be diſcharged at the top, by a cock for that purpoſe.

As the air is a body, it has alſo weight, and gravitates towards the earth, like other bodies, in proportion to its quantity of matter.

*The weight of the air is evident, from a number of experiments.*

 1. If

1. If the hand be laid upon a receiver, open at the top, and the air pumped from under it, the weight of the external air will be felt upon the back of the hand, and will preſs it cloſe down to the receiver.

2. If a glaſs bubble, containing a wine quart, be emptied of its air, and then nicely balanced, as ſoon as the air re-enters, it will preponderate, and will be about 17 grains heavier than when empty.

3. If two braſs hemiſpheres be exhauſted, and the air ſhut out by a cock, they will require a force of about 15 pounds to every ſquare inch to pull them aſunder.

4. If a glaſs bubble, with its neck immerſed in water, be exhauſted of its air, when the air re-enters, it will preſs upon the ſurface of the water, and force it up into the bubble.

5. Let a tall receiver be ſet upon a moveable plate, to which is ſcrewed a pipe with a cock, and exhauſt it, then placing the end of the pipe in water, and opening the cock, the preſſure of the external air will be ſeen forcing the water into the receiver, with great velocity.

6. Take a ſtick of oak, hazel, &c. with a hoop round one end of it, to hold quickſilver, and with wet

Wet leathers fix it in the top of an open receiver, ſo as to be air tight, when the receiver is exhauſted, the weight of the air preſſing upon the mercury in the hoop, will force it through the pores of the wood.

7. If a bladder be faſt tied over the top of an open receiver, as ſoon as the air is ſufficiently rarified below, the weight of the column above will break the bladder, with a conſiderable report.

8. If a piece of hazel, having its ends cut very ſmooth, be fixed in the neck of an open receiver, and the lower end immerſed in water, upon exhauſting, the outward air, by its weight, will ruſh through the pores of the wood, and riſe through the water in fine ſtreams.

9. If a ſquare glaſs bottle be exhauſted, it will be broken into ſmall pieces by the preſſure of the circumambient air.

10. A piece of plain glaſs laid over an open receiver, will be broken in the ſame manner.

11. If a barometer be placed under a tall receiver, as the air is exhauſted, the mercury will fall; when the air re-enters, it will riſe again. From hence it is evident, that the mercury is ſupported in the tube by the weight of the air: and therefore, in fine dry

weather, when the atmofphere is heavieft, it will ftand higheft; on the contrary, in rainy weather when it is lighteft, the quickfilver will be loweft.

From this experiment it is found, that the air will fupport a column of mercury to the altitude of 29½ inches, at a mean. The diameter of the tube makes no difference, the reafon of which will appear evident, when we come to explain the laws of *hydroftatics*. For as the weight of a column of mercury, of any given diameter and altitude, is known, the weight of a column of air, of the fame diameter, is alfo known, and is, at a mean about 14lb. upon every fquare inch; and upon every fquare foot, 18 cwt. or near one ton.—Now, if we fuppofe the furface of a middle-fized man to be 15 feet, it will follow, that he will fuftain a preffure of 13½ tons; which, were it not balanced by the fprings of internal air, could not be fupported.

But the particles of air being extremely fmall, enter into every part of our bodies, and by their elafticity, balance the preffure of the furrounding atmofphere.

12. This is evident by placing the hand upon an open receiver; for as foon as the preffure is deftroyed, the air in the flefh, by its fpring, will fwell out the fkin.

13. A

13. A ſmall receiver, placed over the hole in the pump plate, as ſoon as the air is exhauſted, will be ſtrongly preſſed down by the column of air which is over it.

14. It is ſuppoſed by many, that this and other like effects, are cauſed by *ſuction*, or by ſomething within the glaſs drawing it down through the hole of the pump plate. But this is falſe, *as is ſhewn by experiment*. For if a ſmall glaſs be placed on one ſide of the hole, and covered with a larger, then while the larger is exhauſting, the ſmall one will be looſe; but when the air is let in again, the large one will be ſet at liberty, and the ſmall one, by the weight of the air, will be fixed.

There is no effect in nature, produced by any cauſe, that can be called *ſuction*, except that appellation be falſely applied to the *attraction of cohesion*.

15. Smoaking tobacco, and ſucking the breaſt, are performed by the preſſure of the air. For a vacuum being made in the mouth by drawing back, or bending down, the tongue, the air, by its weight, ruſhes through the pipe, in ſmoaking; and by preſſing upon the breaſt, in ſucking, forces the milk into the child's mouth.

*The elaſticity of the air will appear from the following experiments.*

 16. If

16. If a bladder, containing a ſmall quantity of air, be faſt tied, and placed under the receiver, as the receiver is exhauſted, the bladder, by the expanſion of the included air, will ſwell out, and at length appear full blown.

17. If a glaſs bubble, having its neck placed in water, be covered with a receiver, as the air is exhauſted, that in the glaſs, by its ſpring, will make its eſcape, and will be ſeen riſing through the water in large bubbles.

18. If an egg, having a hole in the ſmaller end, be placed under the receiver, upon exhauſting, the air bubble contained in the great end, will, by its ſpring, drive out the contents.

19. If an egg be ſunk in a jar of clear water, upon exhauſting, the air will be ſeen to riſe, from the pores of the ſhell, in innumerable fine ſtreams.

20. Take a bladder, containing a little air, put it in a proper veſſel, and lay a weight upon it, cover the whole with a receiver, then work the pump, and the ſpring of the air will be ſeen to raiſe the weight,

21. If a ſhrivelled apple be placed under the receiver, and the air exhauſted, the air contained in the apple will expand itſelf, and cauſe the apple to appear plump and ſmooth.

22 If

22. If a piece of dry wood be ſunk in water, and covered with a recipient, upon exhauſting, the air, contained in the pores of the wood, will expand itſelf, and riſe through the water in great quantities.

23. The experiment will ſucceed with green wood, leaves, &c. but the quantity of air thrown out will not be ſo great. From this it is evident, that there are air veſſels in vegetables.

24. If a piece of gold, &c. be put in water under a receiver, on exhauſting, the air contained in the pores of the ſurface of the metal will expand itſelf, and appear all over the ſurface.

25. If a ſmall bladder, with a little air and a weight in it, be faſt tied, and ſunk in water, upon exhauſting, the air contained in the bladder will expand itſelf, and cauſe the bladder and weight to ſwim.

26. Alſo, if a cork be juſt made to ſink, by fixing lead to it, it will be brought to the top by the air bubbles adhering to its ſurface.

27. If a jar of clear water be placed under the receiver, upon exhauſting, the air will expand itſelf, and may be ſeen to riſe from every part of the water in innumerable bubbles.

28. If

28. If we uſe freſh beer inſtead of water, the air bubbles will not burſt, becauſe the beer is more viſcid, but will riſe with a fine frothy head.

29. Join a tall receiver, exhauſted of its air, to the top of a veſſel about half filled with water, a pipe going down near the bottom of the veſſel; open the cock, and the ſpring of the air acting upon the ſurface of the water, will cauſe it to riſe in the receiver with great velocity, and will make a beautiful fountain.

30. If a phial of hot water be placed under the receiver, as ſoon as the preſſure of the air is taken off its ſurface, it will begin to boil with great rapidity. A much leſs degree of heat is ſufficient to cauſe the phenomenon in a *vacuum*, than when under the compreſſion of the atmoſphere. Water with my air pump will boil at 69° of Farenheit's thermometer, and ſpirit of wine at 52° of do.

31. If a fiſh be put into a jar of water, and covered with a recipient, as ſoon as the preſſure of the atmoſphere is removed, the air contained in the air bladder will expand itſelf, and cauſe the fiſh to ſwim; but it will not very readily die.

32. If we put a mouſe, rat, cat, &c. under the receiver, and exhauſt the air, the animal will immediately die. From whence it appears, that air is abſolutely

abſolutely neceſſary for ſupporting the lives of theſe, and all other kinds of large animals.

33. But *inſects, reptiles*, &c. will not readily die *in vacuo*.

34. Air is neceſſary for the ſupport of fire and flame; becauſe burning coals, or a lighted candle, will inſtantly go out *in vacuo*.

35. It is owing to the reſiſtance of the air, that light and heavy bodies do not fall equally faſt. For *a guinea and a feather* will deſcend to the bottom of a tall receiver, when exhauſted, in the ſame time.

36. The mercury in a thermometer, placed under a receiver, falls during the exhauſting, and riſes again when the air returns.

See an ingenious account of theſe phænomena, in the Philoſophical Tranſactions, for 1788, by Eraſmus Darwen, of Derby, M. D.

37. That ſound is conveyed from place to place by the medium of the air, will appear by the following experiments.

If we place a bell upon the plate of the pump, and cover it with a receiver, and the bell be rung, the ſound will be much weaker than when in the open

open air, though the receiver be not exhaufted. If the receiver be well exhaufted, the found will not be audible, except very near the pump; but as a perfect vacuum cannot be made, the fmall quantity of remaining air will faintly convey the pulfes to the glafs, which, by a tremulous motion, will convey them to the outward air. From this it appears, that found moves through the air, without the air being carried along with it.

38. That the preffure of the furrounding air upon the receiver is not the caufe of diminifhing the intenfity of found, appears by the following experiment.

Cover a bell with a receiver, in which let the air remain. Cover this with a larger receiver. Condenfe the air betwixt them, and the found will be equally ftrong, whether there be two or four atmofpheres thrown upon the furface of the firft receiver.

If an elaftic body be ftruck, or otherwife put in motion, it will continue to vibrate backward and forward for fome time. The particles of air, which are near it, will, by its quick vibrations, be put into the fame tremulous motion with itfelf, and they, in their approach to thofe that lie next them, will communicate it to them alfo; and fo on to a confiderable diftance, depending on the intenfity of the ftroke, and the nature of the fonorous body.

Theſe aerial pulſes, or waves, are propagated from the ſounding body, in concentric ſpheres or ſhells, decreaſing in denſity as the ſquares of the diſtances increaſe. Hence a perſon, at the diſtance of one mile from a ſonorous body, will hear the ſound four times as loud as he would do at the diſtance of two miles, &c.

The velocity of ſound, according to the moſt accurate experiments, is at the rate of 1142 feet per ſecond. All ſounds, whether ſtrong or weak, move with the ſame degree of velocity, and nearly as faſt when they move againſt the wind, as when they move with it. But they may be heard much further in the direction that the wind blows, than in the contrary.

The velocity of ſound increaſes with the elaſticity of the air, and is therefore ſomething greater in ſummer than in winter. Yet ſounds are more audible in winter than in ſummer, becauſe the air is more denſe. For the ſame reaſon, ſound is much ſtronger in a valley, than upon the top of a mountain, where the air is leſs condenſed by the weight of the incumbent atmoſphere.

As ſound is propagated from the ſonorous body in all directions, if it happens to ſtrike againſt rocks, buildings, woods, &c. the pulſes will be reflected back, and the ſound repeated, which is called an *echo.*

If a muſical chord be put in motion, all its vibrations, whether great or ſmall, will be performed in the ſame time; and therefore the chord, however ſtruck, will always produce the ſame note.

In order to produce different notes from the ſame ſtring, either the length or the tenſion of the ſtring muſt be altered.

If we take eight muſical ſtrings of the ſame thickneſs and ſtretch them with equal weights, and if we make their lengths as 100, 88.8, 80, 75, 66.6, 60, 53 3, 50, they will ſound the notes of the *diatonic ſcale*, viz. C, D, E, F, G, A, B, C, yet the ſounds of the higher notes would be more agreeable if the ſtrings were ſmaller and longer, and their tenſion leſs.

If two ſtrings perform their vibrations in the ſame time, the note or tone produced is called an *uniſon*, and is the moſt perfect concord. If one ſtring performs two vibrations while the other performs one, they will ſound an *octave*, which is the next perfect. If one performs three for the other two, they will ſound a *fifth*. If one four for the other three, a *fourth*. If one five for the other four, a *third greater*.

If two muſical chords, placed near each other, be tuned uniſon, and one made to vibrate, the other will

will vibrate alſo. If the ſtring which is ſtruck be an octave above the other, the two extremes of the other will ſound uniſon with it, while the middle point remains at reſt. In the ſame circumſtances the ſame effect is produced by all kinds of ſonorous bodies; for the vibrations of the air, when put into a tremulous motion by the ſounding body, agree exactly with thoſe which may be produced by the body at reſt, and the vibrations of this reſting body, which, in ſome faint degree, are cauſed by the firſt impulſes of the vibrating air, are, by its correſponding motion, continually increaſed.

*That the air may be condenſed, is evident, from the following experiments.*

39. Let a ſtrong receiver, with a full blown bladder under it, be firmly ſcrewed down upon the plate of the pump; then, with a ſyringe, or with the pump if it be of Smeaton's conſtruction, force in a quantity of air, and the bladder will begin to contract, or ſhrivel up. Whence it is evident, that the air in the bladder is condenſed, or ſqueezed into a leſs ſpace than it poſſeſſed before; and as ſoon as the cock is opened, and the preſſure removed, it will again expand itſelf, and fill the bladder.

The condenſation ought not to be too great, when the receiver is of glaſs, leſt it ſhould burſt, which might be attended with bad conſequences.

 If

If only a double atmofphere be forced into a receiver of five inches diameter, and eight inches high, there will be a force of 1610lb. acting againft its inner furface; if a treble atmofphere, 3360lb.

40. If a glafs bubble, with its neck immerfed in quickfilver, be placed under the receiver, and a double atmofphere forced in, half the capacity of the bubble will be filled with quickfilver, and the air which, in its natural ftate, filled the whole capacity, will be compreffed into one half thereof.

41. If air be condenfed upon the furface of water in a ftrong veffel, it will caufe it to fpout through the tube of communication with a furprifing velocity, and will make a beautiful fountain, or jet d'eau.

The air is an elaftic fluid, capable of being expanded by heat, and contracted by cold. Hence if any part be heated, it will be rendered fpecifically lighter than the adjoining air, and will therefore rife into the higher parts of the atmofphere; and the neighbouring air, by its weight, will rufh into its place, and thereby a ftream of air or wind will be produced. Thus we find the air rufhing through the key-hole, chinks, crevices, &c. into a clofe room where a great fire is made. And the rarefaction made by the heat of the fun, is the caufe of all the *regular* winds, whether general or periodical. For the air to which the fun is vertical, is rendered hotter

hotter than in any other region, and is therefore conſtantly riſing into the upper parts of the atmoſphere, while the heavier air from north and ſouth, is moving in to ſupply its place. Under the equinoctial it blows nearly from the eaſt point: but as the diſtance increaſes, it varies more and more on both ſides, till about the 30th degree of latitude, where, on the north ſide it blows from the N. E. and on the ſouth ſide from the S. E. But this is to be underſtood only of open ſeas; for the direction is altered by hot ſands, mountains, &c. and the wind generally blows towards the land. Hence we have the reaſon of the periodical trade winds, or monſoons, which blow ſix months in one direction, and ſix months in the contrary, *as is more fully explained in the lecture.*

## LECTURE IV.

# PNEUMATIC CHEMISTRY.

THIS part of philofophy is more particularly confined to the chemical properties of the air, and aeriform fluids.

To diftinguifh thefe fluids from the common atmofpheric air, they have been denominated *gaffes*.

Like common air they are tranfparent, and permanently elaftic; but fome of them are abforbed by water in a fmall degree, others fo rapidly, that it is neceffary to make ufe of quickfilver in order to obtain and preferve them.

There are various kinds of gaffes; fome are natural others artificial productions. Their properties are alfo remarkably different.

All gaffes are a combination of caloric with a particular bafis, either fimple or compound.

The mode of obtaining any kind of gas artificially, is by putting the proper materials in a flafk, the mouth of which is clofely fitted with one end of a bended tube, by means of a piece of cloth, leather, &c. The other end of this tube is placed under the mouth

mouth of a jar, filled with water or quickſilver, and inverted in a baſon of the ſame fluid.

*Carbonic Acid Gas*

Is often found in deep pits, wells, &c. It has commonly been called *fixed air*, from its exiſting in an incorporated ſtate in various ſubſtances; but as this is not peculiar to it, the term is not a proper appellation.

It may be produced by pouring ſulphuric acid, diluted with water, on chalk, marble, ſpar, or any calcareous ſubſtance.

It is copiouſly produced by ale, &c. in a ſtate of fermentation, and reſts on the ſurface of the liquor till diſturbed by agitation.

It is alſo produced in combuſtion, and by reſpiration.

It is much heavier than common air, and may be poured out of one veſſel into another like water.

It is readily abſorbed by water, to which it gives a fine ſparkling appearance, and enables it to become a ſolvent for iron.

Water, ſaturated with this gas, is eſteemed highly

 beneficial

beneficial, and may be prepared to resemble the medicinal waters of Pyrmont, &c.

Ale or beer, containing a due proportion of this gas, is brisk and pleasant; but deprived of it, becomes very insipid.

This gas, taken into the lungs, is fatal to animal life; it also extinguishes flame.

Vegetables will not live in this gas; but water, saturated with it, and applied to their roots, is highly nutritive.

Limestone contains a considerable proportion of this gas in combination, which is disengaged in burning; hence the suffocating vapour in the neighbourhood of lime-kilns.

The lime thus burned, recovers from the atmosphere, in time, its proportion of this gas, and again becomes hard, upon which property depends its great use as a cement for building.

*Hydrogen Gas*

Is so called from its being one of the component parts of water. It has also been termed *inflammable air*, from its readily taking fire and burning.

This

This gas is frequently found in mines, where if a lighted candle be introduced into it, it explodes with great violence.

This gas, as well as the carbonic acid gas, is difengaged in combuftion, putrefaction, &c. and therefore abounds wherever thefe p oceffes are carried on. It alfo exifts in the neighbourhood of marfhes, &c. where it may often be feen burning.

It may be obtained by adding to a portion of iron diluted fulphuric acid, or more copioufly by paffing the fteam of boiling water over red hot iron.

Like other combuftible fubftances, this gas will not burn without common air. And if mixed with a due proportion previous to the light being applied to it, a detonation takes place, which will be louder in proportion to the quantity of oxygen gas in the combination.

Though this gas will burn when the air has free accefs to it, yet it does not affift combuftion in other fubftances; a candle placed in this gas, unmixed, is immediately extinguifhed.

It is alfo unfit for refpiration, and has a very unpleafant fmell.

It is much lighter than common air, nearly as 12

to

to 1; hence its uſe in filling baloons, which, by this being rendered ſpecifically lighter than the air, aſcend.

Of this gas there are ſeveral varieties, ariſing from the varied compoſition of its baſis.

*Carbonated Hydrogen Gas,*

Containing, in combination, a portion of carbon, may be obtained by paſſing the ſteam of water over red hot charcoal; alſo from the combuſtion of wood, or any vegetable ſubſtance, in an iron retort, made red hot.

Coal produces this gas in great abundance, and when purified by paſſing through water, and emitted through a proper orifice, it will burn with a clear flame, and gives a brilliant light.

Another variety of this gas may be obtained by ſuffering common air to paſs through burning oil into an exhauſted receiver. This will burn without exploſion.

*Phoſphorated Hydrogen Gas.*

This gas is obtained by boiling a ſtrong ſolution of pot-aſh, in which is contained a ſmall piece of phoſphorus.

This

This gas is generated in confequence of the decompofition of the water, the hydrogen of which, uniting with a portion of the phofphorus, conftitutes the gas.

The neck of the retort muft be immerfed in water, and as foon as the gas makes its efcape through the water, it takes fire fpontaneoufly, and leaves a curious curling ring of fmoke.

Suddenly mixed with oxygen gas (which requires great caution) it detonates.

*Sulphurated Hydrogen Gas*

May be obtained by pouring muriatic acid, previoufly diluted, on a folution of fulphuret of pot-afh.

Or from a mixture of iron filings and fulphur, melted in a crucible, and afterwards put into a flafk with diluted fulphuric or muriatic acid.

It has a very difagreeable fmell, and is abforbed by water, to which it communicates its peculiar fmell, and is found in feveral waters naturally, as at Harrogate, Wigan, &c.

*Nitrous Gas.*

To obtain this gas pour the nitric acid on brafs, copper, zinc, or iron.

It

It does not exist but in a state of confinement, for on exposing it to the common air, it immediately combines with it, and loses its gaseous form.

This gas is made use of for ascertaining the purity or goodness of air of other kinds, or to find what proportion of oxygen they contain.

When mixed with air perfectly noxious, no change takes place: but mixed with common air, a change in the colour ensues, and a subsequent diminution in the quantity: if mixed with oxygen gas, a more remarkable change in colour takes place, and a much more considerable diminution follows.

It therefore appears that the diminution is proportioned to the quantity of oxygen.

The union of the oxygen and the nitrous gas forms nitrous acid; hence upon combination, the change from the state of gas to the liquid form, and the consequent diminution of the preceding volume of gas.

*Nitrous Oxyd*

Is a gas similar to the former in its constituent parts, only differing in their proportion.

It is procured in its purest form from carbonate of ammonia and diluted nitric acid; the solution afterwards

wards evaporated, then diſtilled in a glaſs retort with a proper degree of heat.

This gas is not, like the former, diminiſhed by adding to it oxygen gas.

It is rapidly abſorbed by water.

Animals confined in it will not live.

It may however be breathed for a time, and produces ſingular ſenſations. The experiment ſhould be made with caution.

*Oxygen Gas*

Is ſo called from its being the principle of acidity. It is alſo the part of atmoſpheric air which ſerves the purpoſe of reſpiration, and hence has been called *pure, vital,* or *dephlogiſticated* air.

It may be obtained from the freſh leaves of plants, placed in water under a receiver in the light of the ſun. Alſo from ſulphuric acid and red oxyd of lead put together in a flaſk : but moſt copiouſly from nitrate of pot-aſh, or oxyd of manganeſe, in an earthen or iron retort, in a ſtrong heat.

It is obtained in the pureſt ſtate from oxygenated muriate of pot-aſh in an earthen retort.

A candle burns in this gas with ſurpriſing brilliancy.

A little pyrophorus thrown into it has a very pleaſing effect.

A piece of iron wire will burn in this gas in a remarkable manner, and is melted during the combuſtion; it is alſo oxydated, or converted into a calx.

A piece of red hot charcoal introduced into this gas is immediately affected by it.

A piece of phoſphorus ſet on fire, and immerged in this gas, burns with a degree of ſplendour inferior only to the light of the ſun.

A given quantity of this gas will ſupport life much longer than the ſame quantity of atmoſpheric air, in the proportion of 6 to 1.

This gas naturally combines with various metals, reducing them to a calx, or oxyd; this combination may be aſſiſted by art, and the proceſs more ſpeedily carried on.

Such oxyds are heavier than the metal previous to the oxydation; their colour alſo varies with the proportion of oxygen combined.

Several

Several of theſe metallic oxyds, as alſo the oxyds of ſulphur, phoſphorus, &c. when combined with a greater proportion of oxygen become acids, ſome of which are alſo capable of different degrees of oxygenation.

Oxygen is ſo ſtrongly combined with ſome ſubſtances, as to be retained in all circumſtances hitherto known.

Several of the acids which we have in a liquid form, may, by depriving them of a part of their oxygen, be converted into the ſtate of gas; but in this ſtate they are very difficult to confine: a few are permanent over water or quickſilver.

*Sulphurous Acid Gas.*

To ſulphuric acid add olive oil, and apply a little heat.

This gas is a compound of ſulphur and oxygen, the latter of which exiſts in a ſmaller proportion than in the ſulphurous acid.

This gas is noxious, but poſſeſſes the property of whitening ſilk.

*Muriatic Acid Gas.*

Pour ſulphuric acid on dried muriate of ſoda, or ſea

 ſalt

ſalt. The product muſt be received over mercury, and is the muriatic acid in the gaſeous form.

It is rapidly abſorbed by water, which, when ſaturated, forms the common muriatic acid.

When emitted into the atmoſphere it produces a white cloud.

If into this gas be introduced ſulphur, phoſphorus, charcoal, &c. an inflammable air is produced.

When mixed with common air, the flame of a candle burning in it appears green, or light blue.

*Nitrous Acid Gas*

Is obtained by heating nitric acid, but it acts upon quickſilver; hence it is difficult to examine its properties.

It effervefces with eſſential oils, and is entirely abſorbed by water, to which it communicates the properties of the nitric acid.

*Fluoric Acid Gas.*

Pour ſulphuric acid on pounded fluor ſpar, or blue John (fluat of lime) in a leaden retort.

The

The product muſt be received in a leaden veſſel, as it diſſolves glaſs and ſilicious earth.

It is abſorbed by water, and muſt therefore be received over mercury.

This is the fluoric acid, which exiſts in the gaſeous form in the common temperature of the atmoſphere.

*Alkaline Air, or Gas,*

Is ammonia in its pureſt form.

To obtain it apply heat to volatile alkali, or mix muriate of ammonia and quicklime, apply heat, and receive the product over mercury.

This gas is rapidly abſorbed by water.

Mixed with ſulphurous acid gas, or muriatic acid gas, they unite, and form the common ſal-ammoniac, which is precipitated like a white cloud.

Air is made noxious by the putrefaction of vegetables, or animal ſubſtances; by the burning of candles; by animal reſpiration; by the calcination of metals; by the efferveſcence of iron-filings and brimſtone; by the effluvia of white paint; by exhalations from putrid marſhes, &c. From hence it

 is

is evident, that much air is daily corrupted, and without ſome remedy, the whole atmoſphere would at length become peſtilential.

How air made noxious is again purified, or rendered fit for breathing, has long been a ſubject of enquiry. But it appears, by ſome late experiments made by Dr. Prieſtly, that *water* and *growing vegetables* tend to reſtore it to a ſtate of purity; which diſcovery may be of the greateſt importance to mankind.

LECTURE

LECTURE V.

# HYDROSTATICS.

Hydrostatics is that part of philofophy which treats of the *properties*, *preffure*, and *laws* of fluids.

A fluid is generally defined to be a body, whofe parts move freely among themfelves, and therefore yield to the leaft partial preffure. From whence it is fuppofed, that the particles of a fluid are fmall, round, fmooth, and hard. That fluids are porous, is evident from different phænomena.

*All fluids, except air, are incompreffible.* That is, they cannot be forced or fqueezed into a fmaller fpace than what they naturally poffefs*.

Hence it follows, that the ocean, and other deep waters, muft be every where of the fame denfity; that is, they will not be more denfe at the bottom than at the top. *Yet the preffure will be in proportion to the depth*, as is eafy to conceive, by fuppofing a fluid compofed of a number of thin plates, piled one upon another. For it is evident, that the higher



* Some have concluded that water may be compreffed in a fmall degree.

the column, the greater will be the preſſure upon the loweſt.

This is proved by putting the open end of a narrow tube, into a wider one almoſt filled with water; for, as the ſmall tube deſcends, the water is ſeen to riſe in it, in proportion to the depth, though reſiſted by the ſpring of the internal air.

The preſſure of fluids, at the ſame depth, *is every way equal;* as upwards, downwards, and ſideways; and is always *in proportion to the perpendicular altitude*, without any regard to the quantity. That is, a ſluice will be equally as much preſſed in the ſide of a pond four yards in diameter, as it would be if the pond was four miles in diameter.

If a piece of flat lead be held cloſe to the bottom of an open cylinder covered with leather, and placed more than twelve times its thickneſs below the ſurface, it will be ſuſtained by the upward preſſure of the water.

Let two round boards be put together with leather, after the manner of bellows; in the middle of the upper board fix a long tube, through which pour water into the bellows; and the higher board will be raiſed by the upward preſſure, though a conſiderable weight be laid upon it.

Let

Let the upper board of these bellows be fixed, and to the bottom fasten a wire, which coming through the tube, may be hooked to the end of a scale beam; then put weights into the scale at the opposite end, till the water be seen rising above the upper board. Now supposing the weight sufficient for that purpose be two pounds, then must the bottom of the bellows necessarily sustain a pressure of that weight, for the two scales are just balanced. If to these weights another pound be added, the water will rise in the tube, till the pressure at the bottom, being increased to three pounds, restores the equilibrium. In the same manner, for every additional pound thrown into the scale, the water will rise through an equal space in the tube, and preserve, by its pressure, a counterpoise.

For example, let us suppose that every pound put into the scale raises the water one inch in the tube; then if it be raised 20 inches, the bottom must be pressed with a force of 20 pounds, although the absolute weight of the water be not more than 2 pounds.

This very singular effect, which is generally called the *hydrostatic paradox*, is thus accounted for. The upward pressure at the same depth, is equal to the downward pressure, and therefore the fixed part is pressed upwards with a force equal to the weight of a column of water of the same altitude with that in the

the tube, and of a diameter equal to the ſaid fixed part, which *part* re-acts upon the water, and cauſes it to preſs upon the bottom with a force equal to the weight of a column of the before-mentioned altitude, increaſed by the depth of the bellows, and of a diameter equal to that of the bottom.

Take an open glaſs cylinder, over one end of which, let a bladder be tied flaccid. Fill the cylinder, to any height at pleaſure, with water, and by its weight the bladder will be made convex at the lower ſide. Put the cylinder gradually into a large veſſel of water, and while the ſurface of that in the cylinder is higher than that in the veſſel, the bladder will continue to be bulged downward. As ſoon as their ſurfaces become level, or of the ſame height the bladder will be flaccid. If the cylinder be ſunk deeper, the bladder will become convex on the upper ſide, by the ſuperior upward preſſure of the water in the veſſel, becauſe its ſurface is the higher.

Let a ſmall and wide tube be joined together at the bottom; pour water into the wide tube, and it will riſe in the ſmall *one* to the ſame height, but not higher. Whence it is evident, that the preſſure is in proportion to the perpendicular altitude. For, were it as the quantities which the tubes contain, the altitude in the ſmall one ſhould be, to the altitude in the wide one, as the ſquare of the diameter of

of the wide tube, is to the ſquare of the diameter of the ſmall one.

From hence we ſee the reaſon of conveying water by aqueducts; or why water may be conveyed to any place not higher than the ſource, though a valley intervene, by means of a bended pipe. For it is evident the water will always riſe to the level of the ſpring, whatever the form of the pipe be.

The preſſure of a fluid againſt the ſides or bottom of a veſſel, may be computed as follows; *for the bottom*, multiply the depth in inches by .03617, and the product thence ariſing, by the area of the bottom, in inches. This laſt product will be the whole preſſure upon the bottom, in pounds avoirdupoiſe.

*For a ſide;* multiply the area under water, in inches, by .03617, and that again by the depth of the centre of gravity in inches; the product will be the preſſure in pounds, as before.

The velocity with which water ſpouts out at the ſide or bottom of a veſſel, by computation ſhould be equal to that which would be acquired by a heavy body in falling from the ſurface of the water to the ſaid hole. But by experiments it is found to fall ſhort (ſee my Treatiſe on Mills, part third). If the ſquare root of the depth in feet is multiplied by 5.3

the

the product will be the velocity in feet, and will always be as the ſquare root of the depth.

A heavy body will fall through a ſpace of 16.13 feet nearly, the firſt ſecond, and will thereby acquire a force which would carry it, with an uniform motion, over a ſpace of 32.26 feet per ſecond.

Therefore, if a hole be made in the ſide of a veſſel, or through the breaſt of a dam, at the depth of 16.13 feet below the ſurface, the water will ſpout out, with a velocity of 32.26 feet per ſecond.

The velocity with which water ſpouts out at holes, made at different depths below the ſurface, is as the ſquare root of theſe depths. *As for example*, ſhould it be required to find the velocity with which a fluid would ſpout through a hole 9 feet below the ſurface, it would be, *As* 4 (the ſquare root of 16) *is to* 3 (the ſquare root of 9) *ſo is* 32 (the velocity at 16 feet below the ſurface) *to* 24 *feet, the velocity per ſecond required.*

Or, if the ſquare root of the depth in feet, be multiplied by 8, it will give the velocity, in feet per ſecond.

The following table (which may be of ſervice to thoſe who are concerned in water works) ſhews the velocity per ſecond with which water ſpouts from

from holes made in the side of a vessel, from one to sixty feet below the surface.

| Depth in Feet. | Velocity per second in Feet. | Depth in Feet. | Velocity per second in Feet. |
|---|---|---|---|
| 1 | 5.3 | 17 | 21.85 |
| 2 | 7.49 | 18 | 22 48 |
| 3 | 9.17 | 19 | 23.09 |
| 4 | 10.6 | 20 | 23.70 |
| 5 | 11.85 | 21 | 24.28 |
| 6 | 12.97 | 22 | 24.85 |
| 7 | 14 01 | 23 | 25.41 |
| 8 | 14.98 | 24 | 25.96 |
| 9 | 15.9 | 25 | 26 5 |
| 10 | 16 76 | 30 | 29.02 |
| 11 | 17.57 | 35 | 31.35 |
| 12 | 18.35 | 40 | 33.51 |
| 13 | 19.11 | 45 | 35.55 |
| 14 | 19.82 | 50 | 37.47 |
| 15 | 20.52 | 55 | 39.30 |
| 16 | 21.2 | 60 | 41.05 |

The quantity of water discharged at any depth below the surface, while the aperture remains the same, will be as the velocity at that depth. *As for example:* should 5.3 pints be dischargrd through a hole,

hole, one foot below the ſurface, in a certain time; then an equal hole, made two feet below the ſurface, would diſcharge 7.49 pints in the ſame time; and ſo on, as in the table.

*Solids immerſed in Fluids.*

If a ſolid be immerſed in a fluid, it loſes juſt ſo much of its weight as is equal to the weight of its equal bulk of the fluid. Take a cylindric bucket, and a ſolid cylinder of braſs, &c. which will exactly fill it. Let the bucket be ſuſpended from the end of a ſcale beam, and the cylinder from the bottom of the bucket. Balance them by putting weights into the oppoſite ſcale. Then place the cylinder in a jar of water, and the equilibrium will be deſtroyed. Pour water into the bucket till it be full, and it will be reſtored again. *Whence it is evident, that the cylinder is reſiſted by the weight of the bulk of water.*

From this it appears, that if a body be lighter than water, bulk for bulk, it cannot deſcend, becauſe it is reſiſted by the weight of its equal bulk of water. If it be heavier, it will loſe ſo much of its weight as is equal to the weight of its bulk of water, and deſcend with the reſt. If it be the ſame weight with water, bulk for bulk, it will remain at reſt in any part of the water. *All which is ſhewn by ſmall glaſs images, whoſe ſpecific gravities may be increaſed at pleaſure.*

Relative

*Relative or ſpecific gravity* is the gravity or weight of one body, compared with the weight of another, of equal magnitude.

If a cubic inch of gold be twice the weight of a cubic inch of copper, then are their ſpecific gravities ſaid to be as two to one.

The ſpecific gravity of any kind of matter is eaſily found by the *hydroſtatic-balance*. For if we ſuſpend the body, whoſe ſpecific gravity we would know, from the bottom of a ſcale, by a fine thread, and then balance it exactly, firſt in *air*, and then in *water*, it will be, as the difference between the weight in water and in air, is to the weight in air; ſo is the ſpecific gravity of water, to the ſpecific gravity of the body required.

Hence, if the weight of the body in air, be divided by what it loſes in water, the quotient will ſhew how many times it is heavier than water.

In order to find the ſpecific gravities of fluids, let a ſolid piece of glaſs be ſuſpended from a ſcale, as before, and exactly balanced in the air; if then it be immerſed in different kinds of fluids, the weights put into the ſcale over it every time, to reſtore the equilibrium, will expreſs the relative gravities of the fluids.

The ſpecific gravities of different bodies, found by the above proceſs, are expreſſed in the following table.

| A cubic Foot of | | weighs | oz. |
|---|---|---|---|
| | Pure Gold | | 19,640 |
| | Standard Gold | | 17,150 |
| | Pure Silver | | 11,091 |
| | Standard Silver | | 10,000 |
| | Lead | | 10,130 |
| | Copper | | 9,000 |
| | Braſs caſt | | 7,856 |
| | Iron | | 7,645 |
| | Tin | | 7,551 |
| | Flint Glaſs | | 2,542 |
| | Slate | | 2,750 |
| | Dry Oak | | 925 |
| | Pit-coal | | 1,272 |
| | Ebony | | 1,177 |
| | Ivory | | 1,862 |
| | Dry Fir | | 546 |
| | Mercury | | 13,610 |
| | Rain Water | | 1,000 |
| | Aqua-fortis | | 1,300 |
| | Spirit of Wine | | 840 |
| | Red Wine | | 993 |

The ſpecific gravity of fluids may be found by pouring a little mercury into a bended glaſs tube open at both ends, and then pouring into each leg a different kind of fluid, and in ſuch quantities that the mercury in each leg may ſtand to the ſame altitude; and if the fluids poured in be of different altitudes, their ſpecific gravities will be reciprocally as thoſe altitudes.

The

The hydrometer is the moſt convenient inſtrument for diſcovering the ſpecific gravities of fluids. The only one made on true principles is always ſunk to the ſame mark in the ſtem, by weights placed on the top thereof. Hence the quantity of fluid diſplaced in every experiment, is exactly the ſame. If, therefore, we add the weight placed on the top, to the weight of the inſtrument, the ſum will be the weight of the fluid diſplaced.

*Example.* If, when ſunk to the proper mark in *water*, the whole weight be 1000 grains; and if, when ſunk to the ſame mark in *rum*, the weight be 928, then is the ſpecific gravity of the former, to that of the latter, as 1000 to 928; the temperature in each being the ſame.

## LECTURE VI.

# HYDRAULICS, &c.

The ſyphon, or crane, is a bended tube, which being filled with water, and then inverted, the outward leg being continued below the ſurface of the water to be conveyed through it, the water in the longer leg, by its weight, will begin to deſcend, and that in the other, by the preſſure of the air, will be forced after it, provided the altitude of the ſyphon above the water, does not exceed 33 feet.

### *Tantalus Cup.*

The phenomenon of this cup is owing to a concealed ſyphon, the higheſt part whereof is lower than the top of the veſſel, one leg reaching below the bottom, and the other communicating with the inſide, near the bottom. As the cup is filled with water, the ſyphon will alſo be filled; or the water will continue to riſe in the cup, till it runs over the bended part of the ſyphon, when the ſyphon will begin to run, and the cup will be emptied.

Intermitting ſprings are accounted for upon this principle. If a ſyphon is formed in the earth, and communicates with ſome cavity near the bottom; and if this receptacle be not ſupplied with water as faſt

faſt as the ſyphon will carry it off, it will then riſe as in the cup, till the ſyphon begins to run, which will continue till the cavity be emptied, or till the water falls below the orifice of the ſyphon, and thus it will ceaſe.

### *The Fountain at Command*

Is a cylindric veſſel, about four inches wide, and five inches high, cloſed at both ends. In one end are inſerted, round the centre, five or ſix ſmall pipes, half an inch long, and one eighth in diameter. In the centre is ſoldered a tube fourteen or eighteen inches long, and half an inch diameter; one end of this tube goes near the top of the veſſel, and on the other are ſoldered three claws to ſtand upon, and which raiſe the lower orifice of the tube about half an inch above the bottom of a cup, in which it is placed; in which bottom is made a ſmall hole. The veſſel being almoſt filled with water through the long tube, and then inverted, it will run out through the ſmall pipes into the baſon, and will riſe till it touches the lower end of the wide tube, and then the fountain will ceaſe to run; for as the air is kept from entering through the long tube, the preſſure of that on the outſide will ſupport the water in the veſſel. But as the water is conſtantly running out of the cup through the ſmall hole in the bottom, as ſoon as it falls below the orifice of the long pipe, the fountain will again begin to play.

*Common Pump.*

The action of this pump depends upon the preſſure of the air. A piſton, with a valve in it, being made to fit the bore of the pump, is put down near a valve which is fixed below in the barrel. A little water is poured upon it to make it air tight, and then, when it is lifted up, the column of air upon it is alſo lifted, and the ſpring of that below in the pump is weakened, and the water, by the preſſure of the air, is raiſed in the barrel, until its weight, together with the ſpring of the internal air, balances the outward atmoſphere. The ſtroke being repeated, when the piſton is put down, the air above the fixed valve makes its eſcape through the piſton valve. When it is raiſed, the air below is again expanded, and the water raiſed as before, &c. until after a number of ſtrokes the water is raiſed above the piſton and brought up into the ciſtern, from whence it may run off.

In conſtructing a pump of this ſort, it is neceſſary that the valve be not fixed too high, viz. not more than 20 or 24 feet, and in ſome caſes not more than 15 feet above the ſurface of the water.

For although the preſſure of the atmoſphere will raiſe a column of water to the altitude of 32 or 34 feet (provided a perfect *vacuum* be made) yet the velocity with which it riſes, at any altitude above

24 feet,

24 feet, is too ſmall where any conſiderable quantity of water is to be raiſed. At the ſurface of the well, the velocity with which it follows the piſton is upwards of 36 feet per ſecond, but decreaſes to the altitude of 34 feet where it is nothing.

If the *wind-bore*, or lower pipe, be made too ſmall in proportion to the working barrel, the water will not riſe with a ſufficient velocity through the valve, to fill the vacuum in the working barrel, left by the piſton, in whieh caſe the pump will be much harder to work; for whatever the column below the piſton wants of 32 feet, it will be added by the preſſure of the atmoſphere.

The velocity with which the piſton riſes, its altitude above the water, and the diameter of the working barrel, are all to be conſidered in computing the diameter of the wind bore, or the diameter of the valve.

Thoſe who are not able to adjuſt the dimenſions by theory, ſhould fix the valve near enough the ſurface of the water, as within 20 feet; for in this there is no diſadvantage in working the pump, as many people ſuppoſe.

For ſhould it be required to raiſe water 40 feet, the weight of water to be lifted every ſtroke will be the ſame, whether the ſpear be 15 or 30 feet long.

In

In the firſt caſe there will be but half the quantity of water upon the piſton, that there will be in the ſecond, but as the weight upon the piſton at every ſtroke, is equal to the weight of a column of water of the ſame diameter with the piſton, and of an altitude equal to the diſtance between the ſurface of the water in the well, and the ſurface of that in the ciſtern, it can make no difference in what part of the pump the piſton plays, provided it be near enough the bottom: for though the water be forced up the lower part of the pump, by the weight of the atmoſphere, yet the ſaid part is firſt exhauſted of its air by the piſton, which is conſtantly preſſed by the column of air above it with a force equal to the weight of the column of water below.

From hence it is evident, that while the working barrel remains the ſame, there can be no advantage in contracting either the lower or upper part of the the pump: for it has been already proved, that *while the bottom or piſton remains the ſame, the preſſure is in proportion to the altitude.*

*Forcing Pump.*

In this pump, the piſton is ſolid, or without a valve. A pipe with a valve in it is fixed in the ſide of the pump, juſt above the fixed valve; ſo that when the piſton is puſhed down, the water is forced out at the ſide pipe, and is hindered from returning

returning by the valve. The ſide pipe may be of any length required, and by it the water may be forced to the tops of buildings, &c.

*Lifting Pump.*

In this pump, the ſpear goes in at the bottom, is wrought by means of a frame, and can therefore only be uſed in deep waters.

*The Draining Pump*

Is made ſquare, with a valve in the bottom; it is moſtly wrought in an inclined poſition, the piſton is made in the form of the fruſtrum of a ſquare pyramid, the edges are fixed with cords to the ſpear. When it is lifted up, the water preſſes it cloſe to the pump, but when it is puſhed down, the ſides bend in, and give way for the water, ſand, gravel, &c. to riſe.

*Archimedes's Screw*

Is a tube open at both ends, coiled round a cylinder. When it is to be uſed it is placed in an inclined poſition, with the lower end in water, and upon turning it round, the water is brought out at the top.

*Gervis's Engine*

Conſiſts of two buckets ſuſpended from wheels, which have their diameters proportioned to the aſcent and deſcent. When the machine is at reſt, the

tops

tops of the buckets are nearly upon a level: they are ſupplied with water at the ſame time, but in ſuch a manner, that the bucket which raiſes the water is firſt filled, after which it runs over into the other. As ſoon as this has received a ſufficient quantity, it begins to deſcend, and raiſes the other, full of water, which, when at the top, empties itſelf through a valve (opened by a lever ſtriking againſt a ſtud) into the reſervoir. At the ſame time the water runs out of the other bucket through a valve opened by a ſimilar contrivance. When both are emptied, they return to the place where they receive the water.

### *Dr. Barker's Mill.*

The cylindric mill is a tall upright tube, into which, near the bottom, and on oppoſite ſides, two horizontal tubes are fixed.

When the water (which runs in at the top) has filled the arms and cylinder, the preſſure againſt the inſides of the arms will be as the height of the cylinder. Suppoſe the altitude to be 20 feet, the preſſure upon every inch will be 10.8lb. If an aperture of 6 inches in area be made in each arm, on contrary ſides, and near the ends; the preſſure on that ſide of the arm will be diminiſhed 64.8lb but will remain the ſame againſt the other ſide; hence there will be a force of twice 64.8lb. or 129.6lb. acting at the ends, to turn the machine round.

*The*

*The Power of the above Mill.*

Let $a$ = the area of one aperture.
$b$ = the length of one arm.
$d$ = the altitude, in inches.
$l$ = .5787oz. avoirdupoife, the weight of a cubic inch of water.
$v$ = velocity per fecond.
$n$ = diftance of the refiftance from the centre.

Then will $adl$ = the preffure when the mill is at reft. And, As $n : b :: adl : \frac{adlb}{n}$ = the force at $n$.

If we wifh to increafe the force by increafing the depth, while the ftream remains the fame, the aperture at the bottom muft be inverfely as the fquare root of the altitude.

Suppofe we make the depth = $4d$.

Then As, $\sqrt{d} : v :: \sqrt{4d} : \frac{2v\sqrt{d}}{\sqrt{d}} = 2v$, hence $\frac{a}{2}$ muft be again divided by 2 or $\frac{a}{4}$ for the area of one aperture, and the force or power of the mill will be expreffed by $2ald$, which is double what it was in the firft expreffion, or as the fquare root of the altitude.

Hence

Hence it appears, that the force will be as the ſquare root of the altitude, while the quantity of water remains the ſame.

But if the aperture remains the ſame, and the water remains ſufficient to fill the mill, the force will be as the altitude.

*Centrifugal Machine.*

Erſkine's centrifugal pump conſiſts of an upright tube, which has a valve at the bottom. Into this tube are fixed two tubes, or arms, at the top, and oppoſite each other. There is alſo a hole in the upper ſide of one of the arms, through which water is poured, till the whole is filled; it is then cloſed, and to ſupport the water in the arms, each is furniſhed with a valve. Then, by means of wheels and cogs, it is turned quickly round a perpendicular axis. The water in the arms acquires a centrifugal force; preſſes open the valves, and flies out, and to ſupply its place, the water is raiſed through the upright tube, by the preſſure of the atmoſphere; hence it is evident, that this pump cannot raiſe water much above 30 feet, nor ought it to be made much more than 20 feet high.

As all the methods of computing the force of the centrifugal pump, that I have ſeen, are exceedingly erroneous, and founded upon falſe principles, I have added the following note.

The

*The Power of the Centrifugal Pump.*

Let $a =$ length of one arm in feet.
$b =$ height in ditto.
$y = a\sqrt{\frac{1}{3}}$ the centre of gyration
$q = 3.1416.$
$t =$ time of a revolution in feconds.
$d =$ 16.1 feet.

Firft, $\frac{2yq^2}{dt^2}$ expreffes the centrifugal force of the water compared with its weight.

Secondly, $\frac{2yq^2}{dt^2} \times a$, the length of one arm, gives the length of a column, the preffure of which is equal to the centrifugal force.

Thirdly, $5.3\sqrt{\frac{2ayq^2}{dt^2} - b}$ expreffes the velocity of the effluent water.

Example. Let $a = 4$; $t = \frac{1}{2}$; $b = 15$.

Then, $\frac{2ayq^2}{dt^2} = 34.1852$, from which take $b =$ 15, and there remains 19.1852, the fquare root of which is 4.38, which multiplied by 5.3 gives 23.21 feet, the velocity of the water per fecond. Let the area of the ends of the arms be required when the above

above pump raiſes one gallon per ſecond. Let $v = 23.21$ feet $= 278.5$ inches; $s = 141$ the inches in half a gallon, the quantity thrown out by one arm; $x =$ area of the end $= \frac{s}{v} = .5062$ inches, and the diameter $= 8$ inches.

Which pump will raiſe 60 gallons per minute to the altitude of 10 feet, but will be too hard labour for one man.

*Newſham's Water Engine.*

The engine generally made uſe of for extinguiſhing fires, conſiſts of two pumps, which alternately force the water into a ſtrong air veſſel, in the top of which a pipe is fixed, and extends near the bottom. When the water is riſen in the veſſel to the bottom of the pipe, the air cannot make its eſcape, but as the water riſes, it compreſſes the air in the crown of the veſſel, which, by its ſpring, forcibly acts upon the ſurface of the water, and cauſes it to ſpout through the pipe with an exceeding great velocity, and by means of a proper contrivance at the top, may be thrown in any direction at pleaſure.

*The Chain Pump,*

Or rag pump, conſiſts of a number of pieces of wood

wood or iron, of the fame fize, which are connected by a ftrong chain, paffing through the centre of each, the ends of which are linked faft together. This chain is ftretched by two fmall wheels, having teeth of a proper fize to admit the pieces of wood; fo that by a winch, fixed upon the axle of the upper wheel, the chain is caufed to afcend on one fide, and defcend on the other. On the afcending fide they rife up a clofe groove, into which they are exactly fitted, fo that they take with them as much water as can be contained between each piece of wood and the next. When they have reached the top, the water runs into a trough, which conveys it away.

### *Bucket Engine.*

The working part of this engine is made with a beam in the form of an ifoceles triangle, the vertical angle of which is very obtufe. The axle is placed in the bafe, and on the two equal legs are faftened two troughs, to the ends of which are hung two large buckets, with a valve in the bottom of each.

By a proper pipe the water is delivered exactly over the axle, and a divifion being placed in the troughs at the vertical angle, it can only run down into one bucket at once. The buckets are fupported by a catch, till nearly full, and then they fall with a jerk alternately, as the divifion is firft

thrown on one ſide the ſtream, and then on the other. When the buckets are at the bottom, they are emptied through the valves, opened by ſtuds.

This is only the machinery for working either common or forcing pumps.

## LECTURE VII. & VIII.

# ELECTRICITY

Is a branch of philoſophy which may be conſidered as in a ſtate of infancy; for although a very great number of experiments have been made, and a great variety of facts are aſcertained, yet they are differently accounted for by different electricians.

Some conſider the effects of electricity to ariſe from the exiſtence of two ſorts, or powers, diſtinguiſhed by the terms vitreous and reſinous.

Others conſider the ſame effects owing to one kind of electricity only, but exiſting in unequal proportions.

All however agree that the electric fire, or electric fluid, is naturally inherent in all bodies; but exiſts in a quieſcent ſtate, till by ſome mode of excitation it is diſengaged, or the natural equilibrium is deſtroyed.

The excitation of vitreous or reſinous ſubſtances, is attended with the appearance of electric fire; but ſubſtances attracted by the one, are repelled by the other: hence the diſtinction of the vitreous and reſinous powers, or, as termed by others, the poſitive and negative.

All ſubſtances, which, by excitation, ſhew any ſigns of electricity, are called *electrics;* and ſuch ſubſtances as exhibit no appearance of it under ſimilar circumſtances, are called *non-electrics*.

Electrics will not convey the electric fluid from one body to another, and are therefore called *non-conductors*.

Non-electrics have a contrary effect, and are of courſe termed *conductors*.

Amongſt the former are glaſs, reſins, amber, ſulphur, all the precious ſtones, ſilk, cotton, feathers, hair, &c.

Amongſt the latter are metals of all kinds, water, and moſt liquids, &c.

Non-conductors, when heated to a certain degree, become conductors, and loſe the power of excitation.

A ſmall quantity of electric fire may be rendered viſible by the

*Electrophorus*,

Conſiſting of a piece of common window glaſs, and a ſmall metallic plate, ſomething leſs than the glaſs; which

which plate is furniſhed with a piece of ſilk, or other electric, to ſuſpend or hold it by.

The plate of glaſs is then excited, and afterwards the plate of metal ſet down upon it, and ſmall ſparks may be taken from the metal.

The quantity which can be thus collected is very trivial compared to the quantity which may be collected by the

*Electrical Machine.*

This is a globe or cylinder of glaſs, ſo fitted up, that it may be turned round upon its axis, and at the ſame time moderately preſſed by a cuſhion covered with ſilk or leather, and having a piece of ſilk attached to it which will reach over the cylinder.

Electrical machines are alſo made with circular plates of glaſs, as alſo by turning pieces of ſilk over rollers, &c.

Metallic bodies are ſaid to be *inſulated* when ſuſpended by, or reſting upon, electrics.

Metallic bodies, when inſulated, may have their quantities of electricity increaſed, which, at the approach of a ball of metal, &c. will make its eſcape

with

with a ſnap, and will ſhine or appear like a ſpark of fire.

In order therefore to accumulate or to condenſe the electric fluid, conductors are inſulated and adapted to the machine, ſo that by means of points they may receive the electric matter as it is collected, and retain it for the purpoſe of making experiments.

If the inſulating pillars were perfectly dry, and no moiſture in the atmoſphere, the electric matter might be retained a great length of time, becauſe dry air is no conductor; but a very ſmall degree of moiſture on the ſurface of the pillar would convey the greateſt part of the electric fluid down upon the floor.

If the air be charged with moiſture, it becomes a tranſporter of the electric fluid, and conveys it away nearly as faſt as it can be collected.

Hence the very great difference between dry clear weather and a damp atmoſphere for conducting electrical experiments.

Bodies which contain unequal portions of electricity, attract each other; if equal portions, they repel.

If the machine be excited, and a feather held at ſome diſtance, it will be attracted.

If

If the feather be held by a thread, which is a conductor, it will remain attached to the machine, conveying away the electric fluid; but if it be suspended by a silk cord, it will be attracted and repelled alternately.

If two pith balls be suspended by a thread from the conductor, they will be equally charged by the electric matter, and repel each other; but will both be attracted by any other substance not electrified.

A glass tumbler, applied to the conductor, may have a portion of electricity thrown upon its surface. If it be afterwards inverted over a few pith balls, they will be attracted and repelled alternately for a considerable time.

Fibrous bodies, as feathers, tufts of silk, &c. placed upon the conductor, are powerfully affected by the electric fluid.

A piece of leaf gold may be suspended between a ball and the conductor without touching either; or it may be caused to vibrate betwixt the two.

Figures, cut out in various forms, will also be attracted and repelled.

Bells, so suspended that one may be electrified, and

and the reſt not ſo, and having balls of ivory ſuſpended betwixt them, will ring with a very ſmall portion of electricity.

Upon the principle of this repulſion are conſtructed

*Electrometers,*

For meaſuring the ſtrength of an electrical charge, or indicating its preſence, of both which kinds there are various contrivances.

The electric fluid is thrown out or received by points, according as the point is attached to the body which is charged or preſented to it.

A pointed wire, fixed in the conductor, throws out a ſtream of electric matter, which may be diſtinctly felt by the hand; or if the flame of a candle be preſented to it, the flame is blown out of its upright direction.

Small vanes, or wheels, made of paper, and properly ſuſpended, will be turned round by this ſtream iſſuing from the point.

In a dark room the ſtream of electric fire may be ſeen, illuminating the point; and there is a very obſervable

obſervable difference between a point emitting and receiving the electric fluid.

Water, being a conductor, may be charged exactly like a piece of metal, and the electric fire will, at the approach of a ball, ſnap from the ſurface of the water.

The quantity of electricity accumulated by a machine, and retained by the largeſt conductors, is inferior in effect to the

*Leyden Phial,*

Which is a common bottle, or jar, whoſe ſurface is partially covered with tinfoil, both on the inſide and outſide.

If a jar thus prepared be inſulated, and connected with the conductor, it will not receive any charge of electricity; but if, while one ſide communicates with the conductor, the other communicates with the earth, the jar will then be ſpeedily charged.

The charge is diſſipated by connecting the two ſides by means of a diſcharging rod, chain, &c.

But if the commnication between the ſides is not complete, no diſcharge takes place.

Therefore

Therefore a charged jar may be touched either inſide or outſide with perfect ſafety, provided the contrary ſide be inſulated.

A jar will be charged indifferently on either ſide, the outſide receiving equally as ſtrong a charge as the inſide.

A number of theſe jars connected with the conductor at the ſame time, form the *electrical battery*.

The effects produced by a battery of this kind are very ſtriking, and require much caution, as perſons have ſometimes been ſeverely hurt by inadvertently receiving the ſhock.

The diſcharge from a battery, being ſuffered to paſs over a piece of glaſs, will break it into ſmall pieces.

If ſuffered to paſs over a piece of leaf gold upon glaſs, it will melt the gold into the glaſs.

If paſſed through a book, will make a perforation through all the leaves.

If paſſed through gunpowder, will ſet it on fire, &c. &c.

A piece of flat glaſs, partially covered with tinfoil, will

will receive an electrical charge, and has generally been called the

*Magic Picture.*

Any perfon, attempting to touch the engraving which covers the tinfoil, receives the fhock.

Any number of perfons, taking hold of hands, may receive an electric difcharge, the effects of which, when moderate, are only momentary, and is felt moft feverely in the joints.

A perfon may alfo be electrified fimilar to the conductor, by ftanding upon an infulated ftool.

A very fmall fpark will fet fire to alkohol, or fpirits of wine, warmed a little.

The electrical piftol, being charged with a proper quantity of hydrogen gas, will take fire by prefenting it to the conductor.

Electricity has been applied to various medical purpofes, and in many cafes with very good effect.

Any part of the body may be electrified, without fuffering the difcharge to pafs over any part but what is intended.

*The Thunder House*

Is a ſmall model, intended to exhibit the effects of electricity, and to prove that ſimilar effects are produced by it and by lightning, differing only in degree.

Various experiments may be made with this and other models, by which the ſafety of buildings, having conductors, is demonſtrated.

Water being a conductor of the electric fluid, rain brings down conſiderable quantities of it in a thunder ſtorm, and its preſence is indicated by the rain electromer, or more ſenſibly by the electromer invented by Bennett.

Water, when electrified, and flowing out from a ſingle aperture, is, by the electric fluid, diſperſed and converted into a ſhower.

From the proceſs of charging the Leyden phial, it appears that when one ſide is electrified poſitively, the other is electrified negatively.

Hence, if the upper regions of the atmoſphere contain more than their common quantity, the ſurface of the Earth ſhould contain leſs, and *vice verſa*, which has always been obſerved to be the caſe in thunder ſtorms.

From

From modern obſervations it is certain, that lightning is a large quantity of electricity, paſſing between bodies which contain unequal portions thereof. Sometimes deſcending from the cloud to the Earth; ſometimes riſing from the Earth to the cloud, &c.

Lightning always precedes the thunder, and is the cauſe thereof. It may be conſidered as a ball, moving through the air with a velocity ſufficiently great to leave a vacuum behind it. The air, which was divided and condenſed in the vicinity of the paſſage, by its elaſticity, immediately coaleſces, and produces the noiſe.

The duration of the thunder-peal is accounted for, in the moſt ſatisfactory manner, from the progreſſive motion of ſound; not by reverberation, or zones of inflammable air, as ſome have ſuppoſed.

If a lightning paſſes from cloud to cloud in various directions, before it reaches the Earth, the time of this paſſage is momentary.

The velocity of light is 200,000 miles in one ſecond; that of ſound, 1142 feet. Hence the lightning will be ſeen the very inſtant that it moves. But if no part of the vacuum ſhould be nearer than one mile, it would be about five ſeconds before the

 ſound

ſound could be heard: or there would be five ſeconds between ſeeing the lightning, and hearing the thunder. And if another part of the vacuum ſhould be at the diſtance of two miles; from that part, the ſound would require ten ſeconds to paſs over it. Hence the thunder-peal would in that caſe continue five ſeconds. And by meaſuring the interval between the lightning and the beginning of the thunder, we may nearly eſtimate the diſtance of the neareſt approach of the lightning, to the place where we are. And the number of ſeconds between ſeeing the lightning, and the end of the thunder, will give us the greateſt diſtance of the ſame lightning. When the interval is one ſecond, the diſtance will be 381 yards.

| | | |
|---|---|---|
| When | 2 ſeconds | 761 yards |
| | 3 | 1142 |
| | 4 | 1523 |
| | 5 | 1.08 mile |
| | 6 | 1-3 |
| | 7 | 1.51 |
| | 8 | 1.73 |
| | 9 | 1.94 mile, or near 2 miles. |

To ſecure buildings from the effects of lightning, a bar of metal ought to be ſo placed, that one end may be elevated above the higheſt part of the building, and the other ſunk deep in the earth, or carried into water.

*Two*

The electric fluid becoming vifible in paffing over electrics, many curious devices and illuminations may be exhibited by means of the electric fpark, as fpirals, letters, conftellations, &c.

The paffage of the electric fpark has alfo the effect of rendering bodies partially tranfparent.

If the air be exhaufted from a tube of glafs, and the tube afterwards applied to the conductor, the electric matter will pafs freely, and is the greateft refemblance of the *aurora borealis*, or northern lights.

Thefe and fome other experiments require a dark room, in order to fee them to any advantage.

*Two lectures are given upon this fubject, illuftrated by experiments made with a cylinder* 19 *inches diameter, and conductors of* 12 *inches diameter, with other neceffary apparatus.*

LECTURE IX.

# OPTICS.

It is manifeſt, from a number of experiments, that *light is a real ſubſtance, or body*, and that it conſiſts of particles inconceivably ſmall; otherwiſe they could not pervade the pores of glaſs, diamond, &c. The wiſdom of the Creator is abundantly manifeſt, and perhaps as fully diſplayed in the ſmallneſs of the particles of light, as in any part of the creation. Light is emitted from every point in the ſurface of a luminous body, in right lines, and with a velocity of 200,000 miles in a ſecond of time, which is inconceivable and unparalleled.

As light is propagated in ſtraight lines, it muſt decreaſe, as the ſquares of the diſtances increaſe; *that is*, if at the Earth we have a certain quantity or degree of light and heat from the Sun, then at twice that diſtance there will be but $\frac{1}{4}$ part of that quantity; and at three times the diſtance but $\frac{1}{9}$ part thereof; but at half the diſtance there will be four times as much, and at one third of the diſtance 9 times as much. So it will be found, that at *Mercury* there is about $6\frac{1}{2}$ times the light that we have; at *Venus* near twice as much; at *Mars* about $\frac{1}{3}$; at

*Jupiter*

*Jupiter* $\frac{1}{28}$; and at *Saturn* $\frac{1}{100}$ part of the light and heat which we have.

If a ray of light, coming from the ſurface of a luminous object, falls upon a plain mirror, it will be ſo reflected, that the *angle of reflection* will always be equal to the *angle of incidence*.

Light, alſo, in paſſing out of one medium into another of different denſity, is *refracted*, or bent out of a ſtraight line, and the more ſo as the medium is more denſe.

The white light of the Sun is *heterogeneal*, or of different kinds, and each kind differently refracted, or bent out of its way in paſſing through the ſame medium, and appears alſo of a different colour. Theſe rays which are *leaſt refrangible*, excite the idea of *red;* the ſecond ſort, of *orange;* the third, of *yellow;* the fourth, of *green;* the fifth, of *blue;* the ſixth, of *indigo;* and the ſeventh, of *violet.*

If a beam of the Sun, coming through a ſmall hole into a dark room, fall upon the ſide of a triangular glaſs priſm, it will, upon the oppoſite ſide of the room, form an oblong and coloured image of the Sun.

Now if theſe different ſorts of light were not differently

differently *refrangible*, the image, after refraction, would continue to be round, but we find it is not; and that the red light is leaft, and the violet the moft refrangible.

That thefe different kinds of light really exift in the light of the Sun, and that the image is not fpread out by the incident rays being difturbed, fhattered, or fplit by the glafs, appears from a number of experiments, *as fhewn in the lecture.*

Light, falling upon the furface of bodies, is in part *reflected*, and in part *imbibed.* If the parts of a body be fo difpofed as to reflect all the rays which excite the idea of red, and imbibe the reft, that body muft appear red. If a body reflects all the green rays, and imbibes the reft, it muft appear of a green colour, &c. Every body, therefore, appears of fuch a colour as would be produced by a compofition of the different kinds of light which it reflects.

Bodies, which reflect one kind of light, and refract the others, will appear of different colours by refraction and reflection.

The phænomenon of the *rainbow* is caufed by the Sun's rays being feparated by the drops of falling rain, *as is fhewn in the lecture*, by filling a glafs globe with

with water, and letting a beam of the Sun, coming through a ſmall hole into a dark room, fall upon it.

If parallel rays fall upon a *concave mirror*, they will be reflected back to a point, diſtant from the vertex of the mirror equal to half the radius of concavity. This is called the *ſolar focus*, or burning point; for the rays of the Sun, meeting in this point, burn very intenſely. There is alſo in this point an image formed of the object from which the rays proceed. But if the object be brought nearer, ſo that the rays do not fall parallel, the image will not be formed in the ſolar focus, but further from the mirror; and as the object is brought nearer, the image will recede, till they meet in the centre of the ſphere of concavity, where they will be of equal magnitude, but the image inverted.

As the object is brought nearer the focus, the image will conſtantly fly off, till the object arrives at the focus, and then the rays will be reflected parallel among themſelves, ſo that no image can be formed. If the object be between the focus and mirror, the image will be formed behind the mirror, erect and magnified.

Parallel rays, falling upon a plain glaſs of equal thickneſs,

thicknefs, cannot be converged to a focus, but will proceed parallel after refraction.

If one fide be plain, and the other convex, parallel rays will be converged to a point, at a diftance equal to the diameter of the fphere of convexity. If it be double, and equally convex, they will meet in the centre of the fphere of convexity.

In thefe points images will be formed of the objects which the rays proceed from. If the objects be brought near, the images will be formed further from the glaffes than the abovementioned points.

If the diftance of the object be equal to twice the focal diftance of the glafs, the image will be formed at the fame diftance on the other fide, and of the fame magnitude with the object, but inverted.

*Concave glaffes* do not form images; but parallel rays, after refraction, proceed diverging as if they came from a point, diftant from the glafs, equal to the diameter of the fphere of concavity, if it be *a plano concave;* but as if they came from the centre, if it be *a double concave.*

The *human eye* is of a globular form, and confifts of three *humours;* the *aqueous, cryftalline,* and *vitreous.*

*vitreous.* Parallel rays are by theſe converged to a focus at the bottom of a perfect eye, and an image is painted of the object they proceed from, upon the *retina.* But if the eye be too convex, the rays will meet before they reach the retina; if too flat, they will tend to a point beyond the retina. The firſt is remedied by concave glaſſes, or by holding the object very near the eye; the laſt by convex glaſſes.

If an object be placed in the focus of a convex glaſs, the rays, after refraction, will proceed parallel among themſelves; and an eye placed on the other ſide, will have a diſtinct view of the ſaid object, which will alſo appear to be magnified: for a perfect eye cannot ſee any thing diſtinctly nearer than 8 inches. Therefore if the focal diſtance of the glaſs be half an inch, the apparent diameter will be increaſed 16 times; if $\frac{1}{4}$ of an inch, 32 times. Hence they become of uſe as magnifiers, or *ſingle microſcopes*, for viewing ſmall objects.

A *compound microſcope* has a ſmall object glaſs fixed in one end of the tube, and an eye glaſs in the other end; the object is placed upon a ſtage a little further from the glaſs than the focus of parallel rays. By this glaſs an image is formed of the object in the tube, and is as much magnified in length as the diſtance between the image and glaſs, is greater

greater than the diſtance between the object and glaſs; which ſuppoſe 8 times: then if the eye glaſs be one inch focal diſtance, the image by it will be magnified 8 times alſo, and by both glaſſes 64 times in length. In moſt microſcopes, a third glaſs is added to increaſe the field of view.

The magnifying power of the *ſolar microſcope* is computed by dividing the breadth of the room by the diſtance between the object and glaſs. Suppoſe the firſt be ſix yards, and the laſt half an inch, then will the object be magnified 423 times in length, 186,624 in ſurface, and 80,621,568 times in ſolidity.

The *camera obſcura* is made of various forms and ſizes. It is intended to exhibit a painting of ſuch objects as are before it. A ſingle convex glaſs forms this painting, and the box is always ſo contrived, that the glaſs can be removed to its proper focus, from the ſcreen on which it is formed.

A *perſpective glaſs* has in one end a convex object glaſs, and in the other a concave eye glaſs, which is placed at its focal diſtance within the focus of the object glaſs. Let the focal diſtance of the object glaſs be 6 inches, and that of the eye glaſs 1 inch; then the diſtance between them will be 5 inches. The magnifying power of this inſtrument

is

is computed by dividing the focal diſtance of the object glaſs by that of the eye glaſs.

The *aſtronomical teleſcope* has in one end an object glaſs, by which the rays are converged to a focus, where an image is formed of the object they proceed from. This image is viewed by an eye glaſs, placed at its focal diſtance from it, in the other end of the tube; and is as much magnified as the focal diſtance of the object glaſs is greater than the focal diſtance of the eye glaſs. All objects ſeen through this teleſcope appear inverted.

The common *terreſtrial teleſcope* has three eye glaſſes of the ſame focal diſtance, by which the image is viewed erect. Its magnifying power is computed the ſame way as the laſt.

It is an imperfection in refracting teleſcopes, that heterogeneal light is not refracted to the ſame point in the axis of the object glaſs; otherwiſe the focal diſtance of the eye glaſs might be be very ſmall, and the magnifying power very great.

This imperfection is in part remedied in *Doland's patent teleſcope*, which is a very great improvement of the common refracting one.

The *reflecting teleſcope* is a wide tube, open at one

I end,

end, and in the other is fixed a concave mirror with a hole in the middle. Rays of light falling upon this are reflected back, and crofs in its focus: after which, in a diverging ftate, they fall upon a fmall concave, placed nearly at its focal diftance from the focus of the great mirror, by which they are reflected back through the hole in the great mirror, and fall upon a convex glafs, by which they are converged to a focus, and form an image which is viewed by an eye glafs in the end of the tube. This telefcope magnifies 8 or 10 times as much as a refracting telefcope of the fame length.

The *magic lanthorn* has a large convex glafs in one fide, and a candle being placed in its focus, the rays, after refraction, proceed parallel to each other, and illuminate a tranfparent painting. At a diftance, in the end of a tube, is fixed another convex glafs by which the rays are converged to a focus, and form an image of the painting, vaftly magnified, upon a white fheet, on the fide of a dark room.

## LECTURE X.

# MECHANICS.

THIS ſcience treats of motion; explains the laws obſerved by moving bodies; and teaches how to compute the force of the mechanical powers, whether ſingle or combined, in machines. By this ſcience the utmoſt improvement is made of every natural power, and the various elements made ſubſervient to the purpoſes of man.

There are three laws which are obſerved by all moving bodies whatever.

The firſt is, *That every body endeavours to continue in a ſtate of reſt, or moving uniformly in a right line.*

The ſecond is, *That the change of motion is always proportioned to the generating force impreſſed, and is always made according to the right line in which that force is impreſſed.*

The third is, *That action and re-action are equal, and in contrary directions.*

*Of the deſcent of bodies in non-reſiſting mediums.*

A body left to itſelf begins to deſcend, or is carried towards the centre of the Earth, by the

power of gravity. This power acts constantly upon all bodies in proportion to their quantities of matter: hence bodies, containing unequal quantities of matter, will descend with the same velocity. A body, in one second of time, will descend through a space of 16.13 feet; at the end of this time, were the attraction to cease, it has acquired a velocity which would carry it with an uniform motion over a space of 32.26 feet in the next second: but the attraction of gravitation acting constantly upon it, its motion continues to be accelerated, and it is carried over a space of 48.39 feet, or three times as far as in the first second. From hence it appears, that falling bodies will be constantly accelerated; that the spaces fallen through will be as the squares of the times, or as the squares of the velocities, viz. if a body in a certain time falls through 16 feet, in twice that time it will fall through 4 times 16 feet, in three times the time, through 9 times 16 feet, &c the *momentum* of a falling body is always as the time of velocity. When the velocity is the same, it is as the quantity of matter, and is found by multiplying the quantity of matter by the velocity.

*Of bodies descending down inclined planes.*

As the length of the plane, is to the height thereof, so is the space passed over by a falling body, to the space descended through on the surface of the plane in the same time. And as bodies are carried down the inclined plane by the power of gravity

gravity, it is evident they will be equally accelerated, as well as thofe which fall in perpendicular directions; that is, whatever fpace they pafs over in one fecond of time, they will in two feconds pafs over four times that fpace, &c. and the velocity at the loweft point will be equal to that which would be acquired by a perpendicular defcent through the altitude of the plane.

While the altitude of the plane remains the fame, the velocity at the loweft point will always be equal, whatever the length be: fo that if a body defcends down a number of contiguous planes, or down a curve, the velocity at the bottom, as alfo the *momentum*, will ftill be equal. The times of defcent down planes of the fame altitude, but of different lengths, will be directly as the lengths.

From the above we may infer, that whether a body defcends through the diameter of a circle, or through any chord of the fame circle, the defcent will be performed in the fame time; and the velocity at the loweft point, will be equal to that which would be acquired by falling through the perpendicular height of the chord.

If, while a body defcends down one chord, another falls through the diameter of the circle, then while it would afcend up the oppofite chord, which would be in the fame time, the falling body would

paſs over four times the diameter of the circle. The times of deſcent in arches, are to thoſe in their reſpective chords, as 1 to .7854. Therefore the length of a pendulum to vibrate ſeconds will be found, by the following proceſs, to be 39.2 inches; for, As 1 (the ſquare of 1 ſecond) is to 16.12 feet, ſo is $\frac{1}{4}$ (the ſquare of $\frac{1}{2}$ a ſecond) to 4.03 feet, the diameter of a circle, in whoſe chord a body would deſcend and aſcend in a ſecond of time. Its radius is 2.01 feet; and as the deſcent in the arch, is to the deſcent in the chord, as 1 to .7854, it will be, As the ſquare of .7854, is to the ſquare of 1, ſo is 2.01 feet, to 3.26 feet, = 39.2 inches. The lengths of pendulums are in the ſame ratio as the ſquares of the times in which they vibrate. Therefore to find the length of a pendulum to vibrate half ſeconds, ſay, As 1 (the ſquare of 1 ſecond) is to $\frac{1}{4}$ (the ſquare of $\frac{1}{2}$ a ſecond) ſo is 39.2 inches to 9.8 inches, the length required, &c.

Bodies, thrown in horizontal, oblique, or upright directions, are called *projectiles*. Every projectile is acted upon by two forces, the *impetus* or *projectile* force, and the *power of gravity* By the firſt, it paſſes over equal ſpaces in equal times; but by the ſecond, it falls through ſpaces which are as the ſquares of the times Every projectile, therefore, moves in a curve, except it be thrown upright, in which caſe, to appearance, they will move nearly in a ſtraight line.

Every

Every body, revolving round a centre, is alſo acted upon by two forces, the *centrifugal* and *centripetal.* The centrifugal ariſes from the firſt impulſe, and tends to carry the body off from the centre: but by the centripetal force it is conſtantly drawn towards the centre. If theſe forces have a certain ratio to each other, the body is kept revolving round a centre in a circle or ellipſis.

In revolving bodies we muſt obſerve the quantity of matter, the diſtance from the centre, and the periodical time, or time in which the body makes one revolution round the centre.

*Two equal bodies revolving round a centre at the ſame diſtance and in the ſame time, will have equal centrifugal forces.*

*If the diſtances and periodical times be equal, the centrifugal forces will be directly as the quantities of matter.*

*If the periodical times and quantities of matter be equal, the centrifugal forces will be in the ſame ratio as the diſtances.*

*If the periodical times be equal, and the diſtances be reciprocally as the quantities of matter, the centrifugal forces will alſo be equal.*

*When*

*When the diſtances and quantities of matter are equal, the centrifugal forces are directly as the ſquares of the velocities, or reciprocally as the ſquares of the periodical times.*

Theſe laws are all demonſtrated in the lectures, by the *central machine.*

The centre of magnitude is a point which is equally diſtant from every part of the ſurface. The centre of motion is that point which remains at reſt, while all the outward parts of the body revolve round it. The centre of gravity is a point in every body, which, if ſuſtained, the whole body remains at reſt: in uniform and homogeneal bodies it is in the middle of a right line drawn between oppoſite angles; in a circle it is in the centre; in a triangle it is in a line drawn from an angle to the middle of the oppoſite ſide, one third of the length of that line from the ſide. From a knowledge of this centre, we account for the phænomenon of the rolling cone, which ſeems to roll upwards between two inclined wires, *as ſhewn in the lecture.* Alſo for the cylinder, which rolls up an inclined plane, while the centre of gravity deſcends. From hence we alſo ſee the reaſon why ſome bodies ſtand more firmly on their baſes than others; for while the perpendicular line, which paſſes through this centre, falls within the baſe of the body, it cannot fall, &c.

If

If a number of bodies be connected together by a line, there will be a common centre of gravity among them, which, if supported, they all remain at reft.

There are generally reckoned fix mechanical powers.

### 1. *The Lever.*

Which is of three forts. The firft has the *weight* at one end, the *power* at the other, and the *fulcrum* or *prop* between them. The fecond fort has the *fulcrum* at one end, the *power* at the other, and the *weight* between them. The third fort has the *fulcrum* at one end, the *weight* at the other, and the *power* between them.

In order to obtain an equilibrium in the lever, the power muft always be to the weight, as the diftance of the weight is to the diftance of the power from the fulcrum: for then the product of the power, multiplied by its diftance, will be *equal* to the product of the weight, multiplied by its diftance from the fulcrum, which is always the cafe when they balance each other. For bodies of unequal magnitude can only balance each other when their *momenta* are equal, and this can only happen when their velocities are reciprocally as their quantities

tities of matter*. The power of every kind of lever is computed by the ſame rules.

### 2. *The Wheel and Axis.*

In this machine the power is applied to the circumference of the wheel, and the weight to the circumference of the axis. Its force is computed by dividing the diameter of the wheel by the diameter of the axis.

### 3. *The Pulley.*

A ſingle pulley, if fixed, does not increaſe the power: for it is evident the weight and power will paſs over equal ſpaces in the ſame time. But in a combination, where one part is fixed, and the other moveable, the power will be to the weight, as unity to the number of ropes which come to the lower or moveable block: or however they be combined, the power will be to the weight, as the velocity of the weight is to the velocity of the power.

4. *The*

* Let $w$ = the weight.
$p$ = the power.
$d$ = diſtance of the weight from the fulcrum.
$n$ = diſtance of the power from the fulcrum.

Then, As $p : w :: d : \frac{dw}{p} = n$; hence if any three of theſe be given, the fourth may be found; for we have

$$n = \frac{dw}{p}, p = \frac{dw}{n}, w = \frac{pn}{d}, d = \frac{pn}{w}$$

### 4. *The Inclined Plane.*

The inclined plane makes an oblique angle with the horizon. The length of the plane is the diſtance, upon its ſurface, between the loweſt point and the higheſt. The altitude of the plane is the perpendicular height from the horizontal line which touches its loweſt point If a body is to be ſuſtained upon the inclined plane, the power will be to the weight, as the height is to the length of the plane; or as the ſine of the angle of elevation is to the radius.

### 5. *The Wedge.*

A line drawn from the middle of the head to the edge, is called the axis, or length of the wedge.

When the direction of the reſiſtance is perpendicular to the axis, the power will be to the reſiſtance, as the breadth of the head is to the length. For the axis is the ſpace paſſed over by the power, and the thickneſs of the head, that paſſed over by the reſiſtance.

### 6. *The Screw.*

The force of the ſcrew is computed by comparing the velocity of the weight with the velocity of the power; for ſuppoſe the diſtance of the threads be one inch, and the length of the lever to which the power

is applied be 3 feet, then, in one revolution of the ſcrew, the weight will riſe one inch, and the power will move through a ſpace of 226,28 inches. From whence it appears, that the power by ſuch a ſcrew would be increaſed above 200 times.

All theſe computations would anſwer very exactly were there no friction; but a very conſiderable part of the force is deſtroyed by friction; ſo that in loaded machines, engines, &c. we may deduct in ſome $\frac{1}{6}$, in others $\frac{1}{5}$, $\frac{1}{4}$, or $\frac{1}{3}$ part of the whole effect.

All machines, however complicated, are compoſed of the ſimple powers, differently combined together, and the force or effect of the whole is found by computing the force of every ſeparate power, and multiplying the products together; as for example, in the common *crane*, ſuppoſe the length of the handle be 18 inches, and the diameter of the nut 4 inches: if 10 ſtone be applied to the handle, it will balance 90 at the circumference of the nut, for it is 9 times as far from the centre. Let the diameter of the great wheel be 2 feet, and the diameter of the axis 4 inches, then, by this, the power will be increaſed 6 times, which, multiplied by the laſt, will give 54; ſo that if 10 ſtone be applied to the handle, it will balance 10 times 54, or 540, at the axis.

LECTURES XI. & XII.

# GEOGRAPHY AND ASTRONOMY.

## *Geography.*

THAT the earth is of a globular form is evident from the ſhadow caſt upon the Moon in a lunar eclipſe, by obſerving ſhips at ſea, and by ſailing quite round it. Yet it has been found, by meaſuring a degree of latitude at the equinoctial, polar circle, and ſeveral other parts, that the earth is not a perfect globe, but an oblate ſpheriod, being a little flatted at the poles. This alſo agrees with the theory of revolving bodies, for were the Earth fluid, as it probably might in part, at the beginning, the parts under the equinoctial would be thrown further from the centre, by the centrifugal force, which is there computed to be $\frac{1}{289}$ part of gravity. That the Earth is not a perfect globe, is alſo proved by the vibrating of pendulums: for it is found, that a pendulum to vibrate ſeconds, muſt be longer at the polar circles than at the equator; and that the difference is more than would be produced by the centrifugal force.

However, when the various continents, iſlands, ſeas, gulphs, rivers, &c. are delineated upon the ſurface of a globe, it may be conſidered as a juſt repreſentation of the habitable world.

 The

The circles of the ſphere are the *equinoctial, ecliptic, meridian, horizon, colures, tropics,* and *polar circles.*

The EQUATOR, or EQUINOCTIAL LINE, is a great circle which runs eaſt and weſt quite round the globe, being every where at an equal diſtance from the poles, or axis, round which the globe turns.

The ECLIPTIC is that great circle, in which the Sun always appears to move. It cuts the equinoctial in two oppoſite points, called *Aries* and *Libra,* and makes an angle with it of $23\frac{1}{2}°$.

MERIDIANS are great circles which paſs through the poles of the world, through the zenith and nadir, and cut the equinoctial line at right angles.

The HORIZON is a great circle which bounds the ſpectator's ſight in the heavens, and is every where equally diſtant from the place where we ſtand. On the artificial globe it is repreſented by a broad wooden circle.

The COLURES are two meridians, one of which paſſes through the beginning of *Aries* and *Libra,* and is called the equinoctial colure; and the other through the beginning of *Cancer* and *Capricornus,* and is called the ſolſtitial colure.

The

The leſſer circles are the two *tropics*, and the two *polar circles*. The *tropic of Cancer* is $23\frac{1}{2}°$ to the north, and the *tropic of Capricorn* $23\frac{1}{2}°$ to the ſouth of the equinoctial. One bounds the Sun's declination on the north, and the other on the ſouth ſide thereof.

The northern *polar circle*, called the *arctic circle*, is $66\frac{1}{2}°$ north of the equator; the ſouthern, or *antarctic circle*, is the ſame diſtance ſouth of the equator.

There are two *frigid zones*; one is ſurrounded by the arctic circle, and the other by the antarctic circle.

There are alſo two *temperate zones*; one lies between the tropic of Cancer and the arctic circle; the other between the tropic of Capricorn and the antarctic circle. All that ſpace which lies between the two tropics, is called the *torrid* or *burning zone*.

The inhabitants of the torrid zone are called *Amphiſcii*, becauſe at noon they caſt their ſhadows different ways at different ſeaſons of the year.

The inhabitants of the temperate zones are called *Heteroſcii*, becauſe their ſhadows at noon always fall one way.

The inhabitants of the frigid zones are called

*Periſcii*, becauſe in ſummer they caſt their ſhadows quite round them.

Thoſe who live under the ſame meridian, but have as many degrees ſouth latitude as we have north, are called *Antiæci*, or *Antæci:* they have the ſame hour, their days are always the length of our nights, and their ſummer is our winter.

The *Periæci* lie under the ſame parallel of latitude, but differ 180° in longitude: their days and nights are always the ſame length of ours; their ſeaſons are alſo the ſame, but they have the contrary hour, or noon, when we have midnight.

The *Antipodes* have as many degrees ſouth latitude as we have north, and alſo differ 180° in longitude, and conſequently are directly under our feet; their day is always the length of our night, their ſummer is our winter, and they have noon when we have midnight.

A climate is ſuch a ſpace of the globe, that in ſummer, the longeſt day on the north ſide (if in north latitude) exceeds the longeſt day on the ſouth ſide, by the ſpace of half an hour. There are 24 climates on each ſide of the equator, between it and the polar circles; and 6 on each ſide between the polar circles and poles, where the length of the days on that ſide of the climate next the pole, exceeds

exceeds the length on the other ſide by a whole month.

The *globe* is divided into three different *ſpheres*. Thoſe who live under the equinoctial, have a *right ſphere*, and have the poles in the horizon. A *parallel ſphere* has the equator in the horizon, and all the circles of latitude parallel thereto. An *oblique ſphere* has one pole elevated above the horizon, and the other depreſſed below it.

LATITUDE of a place, is its diſtance north or ſouth from the equator.

LONGITUDE is the diſtance between the meridians of any two places, and is counted upon the equator.

The ZENITH is that point in the heavens which is directly over our heads.

The NADIR is that which is diametrically oppoſite, or right under our feet.

A CONTINENT is the largeſt diviſion of land, comprehending various *countries*, *empires*, and *kingdoms*, not ſeparated by water.

An ISLAND is a tract of land entirely ſurrounded by water.

A Peninsula is a part of land, all ſurrounded by water, except a narrow neck, called an

Isthmus, by which it is joined to the continent.

A Promontory is a mountainous part of land, ſtanding far into the ſea.

The Ocean is the largeſt collection of waters; it lies between, and environs the continents.

A Sea is a ſmaller part of the ocean, which goes between the continents.

A Gulph is a part of the ſea, every where encompaſſed with land, except one ſmall part called a

Strait, which is that narrow paſſage by which it is joined to the adjacent ſea.

A Lake is a large quantity of ſtagnant water, entirely ſurrounded with land.

The whole ſurface of the globe contains near 200 millions of ſquare miles: the inhabited part 39 millions; the ſea and unknown parts 161 millions. From whence it appears, that there is more than 4 times as much water as land upon the ſurface of the globe.

*Aſtronomy*

## *Aſtronomy.*

Astronomy is that ſcience which diſcovers to us the true motions, magnitudes, diſtances, eclipſes, and other appearances of the heavenly bodies In the *Solar Syſtem*, which is compoſed of the Sun, 6 primary, and 10 ſecondary planets, beſides comets, the Sun is placed in the centre, and the planets revolve round him from weſt to eaſt, at different diſtances, and in different periods; as in the following table.

| | Diſtances in Miles. | | Periods. | | | Diurnal Revolutions. | | Diameter in Miles. | Velocity per Hour in Miles. |
|---|---|---|---|---|---|---|---|---|---|
| | | | Y. | D. | H. | D. | H. | | |
| Mercury | 36 | Millions. | | 87 | 23 | unknown | | 3,000 | 109,700 |
| Venus | 68 | | | 224 | 17 | 24 | 8 | 9,000 | 80,300 |
| Earth | 95 | | 1 | 0 | 0 | 1 | 0 | 7,970 | 68,200 |
| Mars | 145 | | 1 | 321 | 17 | 1 | $0^3$ | 5,150 | 55,000 |
| Jupiter | 494 | | 11 | 315 | 0 | 0 | 10 | 94,000 | 29,000 |
| Saturn | 907 | | 29 | 167 | 0 | unknown | | 78,000 | 22,000 |

The ſpace in which the planets move, ſeems to be void of all matter which can afford reſiſtance; for doubtleſs they continue to move with the ſame velocity which they had at the beginning, which, according

according to the laws of nature, they could not do if they were refifted: for the planets are conftantly acted upon, or kept moving round the Sun by two powers; one is the centripetal force, or attraction of the Sun; by this they are conftantly acted upon and drawn towards the Sun's centre: the other is the centrifugal or projectile force, by which they endeavour to fly off in tangents to their orbits. The projectile force, which remains the fame, was communicated by the Creator at the beginning: and as the attraction of the Sun at every planet is different, fo is the centrifugal force; for it is neceffary that they have a certain ratio to each other, in order to keep the planets revolving in orbits nearly circular. Comets move round the Sun in orbits vaftly eccentric; and, like the planets, always defcribe equal areas in equal times; for as they approach the Sun, their velocity increafes. The diameter of the Sun is 893,760 miles; it turns round its own axis, which makes an angle of 8 degrees with the ecliptic, in fomething lefs than 26 days.

JUPITER has four moons, whofe orbits lie nearly in the plane of the ecliptic. They revolve round him from weft to eaft; the firft at the diftance of 5.6 femidiameters in one day, 18 hours, and 27 minutes; the fecond at the diftance of 9 femidiameters in 3 days, 13 hours, and 13 minutes; the third at the

the diſtance of 14.2 ſemidiameters in 7 days, 3 hours, and 49 minutes; the fourth at the diſtance of 25.3 ſemidiameters in 16 days, 16 hours, and 32 minutes. This planet is alſo ſurrounded with cloudy dark ſtreaks, commonly called his belts, but what they are, is at preſent unknown.

SATURN is attended with five ſatellites or moons: the firſt, at the diſtance of 2 ſemidiameters, revolves in 1 day, 21 hours, and 18 minutes; the ſecond, at the diſtance of 2.4 ſemidiameters revolves in 2 days, 17 hours, and 41 minutes; the third, at the diſtance of 3.6 ſemidiameters, revolves in 4 days, 12 hours, and 25 minutes; the fourth, at the diſtance of 8 ſemidiameters, revolves in 15 days, 22 hours, and 41 minutes; the fifth at the diſtance of 23 3 ſemidiameters, in 70 days, 22 hours, and 4 minutes. Beſides theſe moons Saturn is alſo encompaſſed with an amazing phænomenon, called his *ring*, the diameter of which is computed at 120,000 miles. This ring is inclined to the plane of the ecliptic, about 31 degrees; its nodes are in 19 degrees and 45 minutes of Virgo and Piſces. When Saturn is in thoſe ſigns, the plane of the ring paſſes through the Earth, it will therefore be inviſible, or appear like a ſtraight line upon the diſk of the planet. But when Saturn is in Gemini and Sagittarius, the ring will be moſt open, and in the beſt poſition to be viewed.

The

The *Georgian Sidus*, or new planet, difcovered by the indefatigable *Herfchel*, it is prefumed will be fomething more than 80 years in making one revolution: it is at the diftance of 1,800,000,000 miles from the Sun. Mr. Herfchel has alfo difcovered two moons which attend it. In January, 1790, viewed from the Earth, it was about 8 degrees in Leo, with 39 minutes north latitude. Its mean motion is little more than one degree in three months.

There have been two other hypothefes invented to account for the celeftial appearances, called the *Ptolemaic and Tychonic fyftems. But in the lectures they are fhewn, by the planetarium, to be infufficient to account for the phænomena, and therefore exploded; and the Copernican proved, by unanfwerable arguments and demonftrations, to be the true fyftem of the world.*

As all the planets are retained in their orbits by the attraction of the Sun, fo is the moon by the attraction of the Earth: the Earth and Moon mutually attract each other, in proportion to their quantities of matter. By this power they are connected, and between them there is a common centre of gravity*, at the diftance of 1218 miles from the

* The diftance of this centre is found as follows:

Let $e$ = the quantity of matter in the Earth = 45.
$m$ = the quantity of matter in the Moon = 1.

Let

the Earth's ſurface. It is this centre that deſcribes the great orbit round the Sun, and not the Earth itſelf, for both the Earth and Moon revolve round this centre once a month. Hence the Earth will be about 11,000 miles nearer the Sun when the Moon is full than when ſhe is changing.

The EARTH in one day turns round its own axis, and in one year is carried round the Sun, with its axis inclined to the plane in which it moves, making an angle therewith of $66\frac{1}{2}$ degrees, and always retains its parallelism, by which means the poles alternately incline towards the Sun. When the Earth is in libra, the Sun appears in the equator, and the circle of illumination paſſes through the poles of the world: the days and nights are now of an equal length on every part of the globe. But while the Earth moves from Libra to Capricornus

Let $a$ = diſtance between the Earth and Moon = 240,000.
$x$ = the diſtance between the centre of the Earth and the centre of gravity

Then (per mechanics) we ſhall have, $ex = ma - mx$; and $x = \frac{ma}{e + m}$, viz. *if the quantity of matter in the Moon be multiplied by the diſtance between the Earth and Moon, and that product divided by the ſum of the quantities in the Earth and Moon, the quotient will be the diſtance from the Earth's centre* = 5,218 miles.

Capricornus, the north pole will conſtantly turn towards the Sun, and the ſouth pole from it; during which ſpace, the days in northern latitudes are conſtantly increaſing, and the nights decreaſing. When the Earth comes to the beginning of Capricornus, we have the longeſt day, and ſhorteſt night, and the Sun appears in the oppoſite ſign, Cancer. At this time the whole northern frigid zone is illuminated, and the ſouthern obſcured in darkneſs. The circle which divides between the light and dark hemiſphere, juſt touches the polar circles, ſo that at every place, except the equinox and poles, the days and nights are of unequal lengths. After the earth has paſt the beginning of Capricornus, the north pole begins to turn from the Sun, and the ſouth pole towards it. The days in northern latitudes again begin to ſhorten, and in ſouthern latitudes to lengthen. When the Earth comes to the beginning of Aries, the poles are equally diſtant from the Sun: the circle of illumination again divides all the parallels into equal parts, and the days and nights are every where of an equal length. As the earth moves forward from Aries to Cancer, the days in northern latitudes will continue to ſhorten, and in ſouthern latitudes to lengthen. When the Sun appears in the beginning of Capricornus, which happens when the Earth arrives at the beginning of Cancer, the days in northern latitudes are of the leaſt length, and the nights of the greateſt; at which time we have

have the middle of winter. The whole northern frigid zone is now obſcured in darkneſs, and the ſouthern frigid zone all illuminated. When the Earth has paſſed this point, the north pole will gradually turn towards the Sun, and the ſouth pole from it. The days conſtantly increaſe, and the nights contract, while the Earth moves through that half of the ecliptic. When the earth comes to the firſt point of Aries, it has made one revolution round the Sun. The days and nights, as at firſt, are now equal all over the Earth. Whence the cauſe of the different ſeaſons, and different lengths of days and nights is evident. *Explained by the Orrery.*

*The 12 ſigns of the Ecliptic.*

| Northern Signs. | | Southern Signs. | |
|---|---|---|---|
| ♈ | *Aries,* | ♎ | *Libra,* |
| ♉ | *Taurus,* | ♏ | *Scorpio,* |
| ♊ | *Gemini,* | ♐ | *Sagittarius,* |
| ♋ | *Cancer,* | ♑ | *Capricornus,* |
| ♌ | *Leo,* | ♒ | *Aquarius,* |
| ♍ | *Virgo,* | ♓ | *Piſces.* |

The orbit of the moon makes an angle of 5 degrees and 20 minutes with the plane of the ecliptic, and interſects it in two oppoſite points, called nodes, one of which is called the Dragon's-

 head,

head, and the other the Dragon's-tail. When the Moon is in these points or nodes, she has no latitude; but when she is in any other part of her orbit, she is said to have north or south latitude, according as she is north or south of the ecliptic. In the *Orrery* the Moon is carried round by a syderial plate, on which are engraved the signs of the ecliptic. On another plate is also engraved her age, the distance from her nodes, and latitude; by which, when the orrery is rectified, her age, place in the ecliptic, distance from her nodes, and latitude, are, for any day, pointed out. The nodes of the Moon do not remain fixed in the same part of the ecliptic, but have a retrogade motion, and make one revolution in 18¾ years. This motion of the nodes is the cause of various phænomena: it is owing to this, that the moon, once in 19 years, goes further, both north and south, than at any other time, and that the eclipses always happen at different seasons of the year, &c.

The Moon, like all the planets in the system, is an opaque or dark body, and shines upon the Earth by reflection from the Sun; therefore, as the Moon is constantly moving round the Earth, it is evident, that when she is between the Earth and Sun, her dark side will be turned towards the Earth, and she will be invisible. As she moves from conjunction, her illuminated side will gradually turn

towards the Earth, till ſhe be oppoſite to the Sun, when ſhe will appear full. After which time ſhe will again conſtantly decreaſe, till the conjunction or change. *Shewn by the orrery.*

While the Moon makes one revolution round the Earth, ſhe alſo turns once round her axis, and of conſequence ſtill keeps the ſame ſide towards the Earth; ſo that a ſpectator in the Moon would always ſee the Earth, which is a *moon* to the Moon, in the ſame part of the heavens, and it would appear, when full, about 13 times larger in ſurface than the full moon appears to us. As the moon only turns once round her axis in a lunation, one lunar day and night will be the length of 29½ of ours. The moon in the ſpace of 27⅓ days, moves through all the ſigns of the ecliptic, or quite round the Earth: this is called the ſyderial day. The reaſon that ſhe is not again in conjunction with the Sun, is owing to the Earth's progreſſive motion in its orbit, by which the Sun appears to have moved through near a whole ſign to the eaſt, ſo that the Moon will yet require about 2⅙ days to come up with the Sun; which ſpace of time is called the difference between her periodical and ſynodical revolutions, or between her ſolar and ſyderial day.

The Moon, ſome days before and after the change, appears cuſped; and the poſition of theſe

 cuſps

cuſps, at different times of the year, is very different; but always the ſame at the ſame ſeaſon. *Shewn by the Globe.*

The different angles, which different parts of the ecliptic make with the horizon, when riſing, is the cauſe of that phænomenon we call the Harveſt Moon: Virgo and Libra make the greateſt angle; Piſces and Aries the leaſt; ſo that in a given time, a greater length of the ecliptic riſes in theſe ſigns than in any other; and did the Moon move in the ecliptic, ſhe would riſe about 26 minutes later every night for 6 nights together. But as the orbit of the Moon does not lie in the plane of the ecliptic, ſhe will ſometimes riſe with leſs difference of time, and ſometimes with more. For when her north node is in Aries, and her ſouth node in Libra, her orbit will make the leaſt angle with the horizon, at the riſing of Aries, that can be. In this latitude, it will not be more than $7\frac{1}{6}$ degrees, and ſhe will riſe for 6 nights within one hour and 35 minutes of the ſame time; or ſhe will be about $\frac{1}{4}$ of an hour later of riſing every night: but ſhe will differ $1\frac{1}{4}$ hour every morning in her ſetting.

When the ſouth node is in Aries, and the north node in Libra, the Harveſt Moon will be leaſt advantageous; ſhe will differ near twice as much in her riſing, as ſhe did in the laſt poſition of her nodes; the reaſon whereof appears plain by the *orrery*.

The

The Moon riſes with the ſame difference of time once in every lunation, as ſhe does in harveſt; but as this does not happen at the full moon, at any other time of the year it is not much noticed. The north node will not be in the beginning of Aries before the year 1820, when we ſhall have the Harveſt moons to the greateſt advantage.

At the equinoctial they have no Harveſt Moon; for an equal quantity of the ecliptic always riſes in the ſame time. But as the latitude increaſes, the angle, which the ecliptic makes with the horizon, at the beginning of Aries, gradually decreaſes, till we come to the polar circle, where there is no eaſtern angle, and of conſequence one half of the ecliptic riſes at the ſame time. In this latitude, the Moon does not differ more than 1 hour in her riſing, for 15 days, but is 23 hours later in her ſetting.

An eclipſe of the Sun is cauſed by the Moon coming between the Sun and the Earth; and is either total or partial. In like manner, an eclipſe of the Moon is cauſed by the Earth intervening, or coming between the Moon and the Sun; ſo that the Moon loſes her light in paſſing through the Earth's ſhadow. If the orbit of the Moon was in the ſame plane with the orbit of the Earth, there would be an eclipſe of the Sun at every new Moon, and an eclipſe of the Moon at every full. But this

is prevented by the latitude of the Moon, except ſhe be within 12 degrees, 2 minutes, and 9 ſeconds of the node at the time of the full, or within 18 degrees and 20 minutes at the time of the change; which diſtances are called the limits. The nodes, which almoſt retain their paralleliſm, only come in a line with the Sun twice in a year, and therefore there can only be two ecliptic ſeaſons in one year. The limits are not always the ſame, owing to the different diſtances of the Sun and Moon from the Earth, at different times. When the ſolar limit is leaſt, the Sun will paſs over it in 28 days: and when greateſt, in 32 days: in which time, the Moon may come twice in conjunction with the Sun, and ſo cauſe two ſmall eclipſes. However, in every ſolar limit, there is one eclipſe very certain. When the lunar limit is leaſt, the Earth's ſhadow will paſs over it in 19 days; and when greateſt, in about 24 days So that the Moon cannot be eclipſed more than once; but may, and often does, paſs the limit without ſuffering an eclipſe.

The earth has a third motion, whereby the pole of the world is conſtantly moving round the pole of the ecliptic By this motion the equinoxes fall 50 ſeconds ſooner every year than the year before; and the fixed ſtars, by it, appear to move 1 degree eaſtward in 72 years. Since obſervations have been made upon the ſtars, they have moved through almoſt a whole ſign; for the conſtellation which was

once

once in Aries, is now in Taurus; and the conſtellation of Taurus is now in Gemini. By this motion the ſeaſons are conſtantly moving backward, or in *antecedentia*, and would make one revolution in 25,920 years. If the world continues 12,960 years, the longeſt day, in northern latitude, will be when the Sun enters Capricorn, and the ſhorteſt, when he enters Cancer.

All the ſtars which are viſible in the heavens, except five planets, are called *fixed ſtars*, and ſeem to be fixed in the ſame part of abſolute ſpace. The motions which they ſeem to have, are cauſed by the motion of the Earth. For if the Earth turns round its axis in 24 hours from weſt to eaſt, they muſt appear to move from eaſt to weſt. The fixed ſtars are at immenſe diſtances from the Earth or Sun. Was a body to fly from the Sun with a velocity of 8 miles per minute (which is about as ſwift as a cannon ball) it would arrive at the orbit of Mercury in 8¼ years; at Venus in 16½ years; at the Earth in 22¾ years; at Mars in 34½ years; at Jupiter in 117¾ years; at Saturn in 215¾ years; but it is ſuppoſed it would not reach the neareſt of the fixed ſtars in leſs than 700,000 years. However, their diſtance is utterly unknown, being immeaſurable, and inconceivable. It is ſuppoſed, that the different degrees of brightneſs or ſplendour which we obſerve amongſt the ſtars, is owing to their different diſtances from us, and not to any

difference

difference in their magnitude; for it is moſt likely, that they are equally diſtant from each other, as they are from the Sun. They ſhine by their own native or unborrowed light, and are innumerable: for by a teleſcope, thouſands may be ſeen, which are inviſible to the naked eye. We cannot, therefore, ſuppoſe that theſe unſeen ſtars were placed in the heavens, in order to ſupply the inhabitants of the Earth with a faint light in the night, for which purpoſe, ſome think the reſt of the ſtars were made: neither can we ſuppoſe that they were made to declare to the Earth the greatneſs and power of the Creator, becauſe very few of the race of mankind have ſeen them, or heard of their exiſtence; nor can we think that the Almighty has created any thing in vain: but we may reaſonably conclude that they are Suns, or fountains of light, illuminating ſyſtems of planets, whoſe motions are controlled by their attractive power; and that the ſtars, which are inviſible to the inhabitants of the Earth, proclaim the glory and wiſdom of the Deity to other intelligent beings, dwelling in worlds placed far beyond the utmoſt bounds of our ſight. This hypotheſis diſplays the greatneſs and dominion of the divine Being. This confines not the creation within the narrow bounds of the ſphere of fixed ſtars, but ſuppoſes it extended through the regions of immeaſurable ſpace.

This wide machine, the univerſe, regard,
With how much ſkill is each apartment rear'd!
The Sun, the ſource of light, prodigious maſs,
Of this our ſyſtem holds the middle place.
Mercury, the neareſt to the central Sun,
Does in an oval orbit, circling, run;
But rarely is the object of our ſight,
In ſolar glory ſunk, and more prevailing light.
Venus, the next, whoſe lovely beams adorn
As well the dewy eve as opening morn,
Does her fair orb in beauteous order turn.
The Globe Terrestrial next, with ſlanting poles,
And all its pond'rous load, unwearied rolls.
Mars, next in order, further from the Sun,
Does in a more extenſive orbit run.
Then we behold bright planetary Jove,
Sublime in ſpace, through his wide province move;
Four ſecond planets his dominion own,
And round him turn, as round the Earth the Moon.
Saturn, revolving in a higher ſphere,
Is by five moons attended through his year:
The vaſt dimenſion of his path is found
Five thouſand million Engliſh miles around.
The Georgian Sidus, or the Herſchel Star,
Revolves ſupernal in his duſky car.

Yet is this mighty ſyſtem, which contains
So many worlds, ſuch vaſt ætherial plains,
But one of thouſands, which compoſe the whole,
Perhaps as glorious, and of worlds as full.

The

The ſtars which grace the high expanſion, bright
By their own beams and unprecarious light;
Tho' ſome near neighbours ſeem, and ſome diſplay
United luſtre in the milky way,
At a vaſt diſtance from each other lie,
Sever'd by ſpacious voids of liquid ſky.
All theſe illuſtrious worlds, and many more,
Which, by the tube, Aſtronomers explore;
And millions which the glaſs can ne'er deſcry,
Loſt in the wilds of vaſt immenſity,
Are *ſuns*, are centres, whoſe ſuperior ſway
Planets of various magnitudes obey.

If we, with one clear comprehenſive ſight,
Saw all theſe ſyſtems, all theſe orbs of light;
If we their order and dependence knew,
Had all their motions and their ends in view,
With all the comets that in æther ſtray,
Yet conſtant to their time and to their way:
Would not this view convincing marks impart
Of perfect wiſdom, and ſtupendous art?

*Blackmore.*

APPENDIX.

# APPENDIX,

CONTAINING

*Supplementary Lectures,*

WHICH ARE DELIVERED OCCASIONALLY.

# *APPENDIX.*

## 1. MILLS.

Accompanied by experiments on a model of a water-wheel, &c.

On the effects of falling bodies.

On impulse and accelerated motion.

The moving power compared with the velocity of the wheel.

On the application of water.

Experiments with different cog-wheels.

On the greatest effect of a given power.

The size of the wheel compared with the fall.

On the velocity produced by different powers.

## 2. STEAM ENGINES.

The steam engine consists of a large beam, boiler, cylinder, &c. In the cylinder, which stands upright, a piston is suspended from one end of the beam, and to the other are fixed the pump rods. The

cylinder and boiler are made to communicate by means of a pipe, in which is placed a plate called the regulator. The boiler is filled with water to a certain depth, which, by fire, is converted into a vaſtly elaſtic ſteam*, the ſtrength of which is known by its lifting a valve at the top of the boiler, called the ſteam clack. When the regulator is open, the ſteam enters into the cylinder, and drives out the air through a ſmall hole, covered with a valve, called the ſnifting clack. When the cylinder is filled with ſteam, the regulator is ſhut, and the injection cock is opened, by which a jet of cold water is let into the cylinder from a ciſtern fixed above. This jet condenſes the ſteam, and makes a ſufficient vacuum for the piſton to deſcend, which is immediately brought down by the weight of the atmoſphere. In its deſcent it ſhuts the injection cock, and

* It has been maintained by many, that water, when converted into ſteam, fills 13,000 times its original ſpace. But from various experiments, made in order to aſcertain the expanſion in the cylinders of ſteam engines, I conclude it is much leſs. When the boiler ſtands at a diſtance, the ſteam is cooled, and part of it is condenſed by the tubes in which it is conveyed; much of it is alſo condenſed by the cylinder. By many experiments made on a cylinder 3 feet in diameter, one gallon of water produces about 800 gallons of efficacious ſteam. By other experiments made by Mr. Bateman, of Whitehaven, with a cylinder, five feet, eight inches diameter, one gallon of water will produce 1532 gallons of ſteam, but never more.

and opens the regulator; the ſteam again enters into the cylinder, and balancing the preſſure of the air, the piſton is raiſed by the weight of the pump rods at the other end of the beam; as it riſes, it ſhuts the regulator, and opens the injection cock: the ſtroke is again repeated, and the water in the pumps is raiſed, and diſcharged at the top.

The ſteam is ſeldom much ſtronger or weaker than the outward air: if it be $\frac{1}{15}$ ſtronger, the engine will work well. At a mean, the preſſure upon every ſquare inch of the piſton will be 14lb. and upon every foot 18cwt. But in practice the weight at the other end of the beam, ſhould not be more than half the preſſure upon the piſton, in order that the engine may ſtrike ſufficiently faſt.

The ſteam engine has lately been made with an inverted piſton, to ſave the expenſe of a beam. The contrivance is ingenious, but it does not work any thing near ſo well as when made with a beam.

*Patent Steam Engine.*

Since the firſt invention of the ſteam engine, by Meſſrs. Newcomen & Cowley, of Dartmouth, towards the latter end of the laſt century, it has undergone ſeveral alterations; the greateſt of which has been made by Meſſrs. Bolton & Watt. Inſtead of the preſſure of the air, they have ſubſtituted

 the

the elaſtic force of the ſteam; and inſtead of condenſing, as in the common form, a vacuum is made in an adjoining veſſel, into which enters a jet of cold water, which, with the condenſed ſteam, is removed by a pump. By this contrivance, the cylinder is always kept hot, and conſequently requires leſs ſteam. In this conſtruction, the top of the cylinder is cloſed; a rod paſſes through a collar in the cover; and a communication is occaſionally opened between the top and bottom of the cylinder.

When this engine is applied to communicate a rotatory motion, the ſteam alternately preſſes upon the upper and lower ſide of the piſton, which, in this caſe, is not ſuſpended from the beam by a chain, but fixed in ſuch a manner, as to preſs the beam with equal force, whether riſing or falling.

## 3. THE SOLAR MICROSCOPE.

This can only be exhibited on a fine clear day.

A great variety of objects, as ſections of twigs, roots, &c. the eyes, wings, legs, &c. of ſmall inſects. are exhibited by this inſtrument much magnified The cryſtallization of ſalts, and the curious and different forms aſſumed, are very intereſting.

By the opaque microſcope pieces of coin, &c. are magnified in a ſimilar manner.

The

The ſcioptic ball alſo ſerves the purpoſe of a camera obſcura, and when the Sun ſhines clear, forms a beautiful landſcape within the room.

The ſpots of the Sun, when there are any viſible, may be exhibited in a room, upon a ſcreen, by adapting a teleſcope to the apparatus.

The colours of the rainbow illuſtrated by priſms, &c.

## *Private Lectures or Instructions*

Are alſo given in any of the foregoing ſubjects, the general principles of Chemiſtry, and different branches of the Mathematics, to ladies or gentlemen wiſhing to be more fully acquainted with the principles of the ſciences.

AN

# EXPLANATION

OF

## *Technical Words, Terms, &c.*

Ufed in the foregoing Lectures.

### *A.*

*Acid*, four, fharp.
*Accumulate*, to heap up, to gather together.
*Adhefion*, a cleaving, or fticking to.
*Alkali*, a fixed falt, or fubftance that will ferment with an acid.
*Ambient*, encompaffing.
*Analogy*, ratio, proportion.
*Aperture*, an opening, hole, &c.
*Aphelion*, that point in a planet's orbit which is fartheft from the Sun.
*Apparatus*, inftruments for performing experiments.
*Atmofphere*, the air.

### *C*

*Capillary tube*, a tube with a bore as fmall as a hair.
*Central*, of or belonging to a centre.
*Circumambient*, furrounding on all fides.
*Cohefion*, fticking together.

*Comprefs*,

*Compreſs*, to preſs together.
*Concave*, hollow.
*Concentric*, that have the ſame centre.
*Condenſe*, to make thick or cloſe.
*Conjunction*, a meeting of two planets, &c. in the ſame degree.
*Contact*, touching each other.
*Convex*, round, protuberant, like the ſurface of a globe.
*Convergent*, tending to, or meeting in one point.
*Counterpoiſe*, to balance.
*Cuſps*, the horns of the Moon, &c.

*D*

*Deſcent*, a going down.
*Dichotomiſed*, diſſected, divided into two equal parts.
*Diſk*, the viſible ſurface of a planet, &c.
*Diurnal*, daily, belonging to the day.
*Divergent*, ſpreading, or ſeparating.

*E*

*Ebullition*, boiling, &c.
*Eccentric*, that hath different centres.
*Eclipſe*, a deprivation of light.
*Effervſcence*, waxing or growing hot.
*Effluvia*, the very ſmall particles emitted from bodies.
*Elaſtic*, ſpringy.
*Ellipſis*, an imperfect circle, and oval-like figure.
*Emerſion*, a riſing out, or appearing again.
*Epitome*, an abſtract, or ſhortening.

*Epocha*,

*Epocha*, or *Æra*, a fixed point of time from whence the ſucceeding years are numbered.

*Equilibrium*, an even balance.

*Evaporate*, to exhale, or reſolve into vapours.

*Exhauſt*, to draw out, or empty.

*Expanſion*, a ſwell, or increaſe of bulk.

*Exploſion*, a noiſe, or report.

*External*, outward.

*F*

*Fibres*, ſmall threads, or filaments.

*Flaccid*, looſe, not tight.

*Focus*, that point where all the rays of the Sun which fall upon a concave mirror, or lenſe are collected.

*G*

*Gibbous*, round, convex, or bunched out.

*H*

*Halo*, a circle appearing round the Moon, &c.

*Hemiſphere*, half of a globe or ſphere.

*Heterogeneal*, of different kinds or ſorts.

*Homogeneal*, of the ſame ſort.

*Horizontal*, level, parallel to the horizon.

*Hypotheſis*, a ſuppoſition, &c.

*I*

*Imbibe*, to abſorb, or drink in.

*Immerge*, to immerſe, or plunge in water.

*Immenſe*, infinite.

*Impetus*, a blow, or impulſe.

*Incidence*,

*Incidence*, a falling upon.
*Infulated*, fupported by an electric balance.
*Interftice*, a diftance, or fpace between.
*Irradiate*, to fhine upon, or enlighten

*L*

*Lateral*, of or belonging to the fide.
*Lenfe*, a glafs ground convex.
*Longitudinal*, lengthways.

*M*

*Medium*, that peculiar conftitution of any fpace or region through which bodies move.
*Mephetic*, noxious.
*Momentum*, the whole force with which a moving body ftrikes againft another in its way.

*N*

*Nocturnal*, of or belonging to the night.
*Noxious*, poifonous, deftructive.
*Nubilous*, cloudy, gloomy.
*Nucleous*, the head of a comet, &c.

*O*

*Oleaginous*, oily, or full of oil.
*Opaque*, dark, fhady.
*Orbit*, the path of a planet or comet.
*Orifice*, a hole, aperture, or mouth.

*P*

*Particles*, the fmalleft parts of matter.
*Percuffion*, a ftriking.

*Perihelion*,

*Perihelion*, is that point in a planet's orbit which is nearest to the Sun.

*Perforate*, to bore, or pierce through.

*Phases*, the different appearances of the Moon, &c.

*Phænomenon*, signifies an appearance, effect, or operation of a natural body.

*Preponderate*, to outweigh.

*Projectile*, a body thrown or projected from the Earth.

*R*

*Ratio*, reason, proportion.

*Rarefy*, to make thin.

*Recipient*, a glass receiver from the air pump.

*Reflection*, a beating back.

*Refraction*, turning aside, or out of a straight line.

*Refrangible*, capable of being refracted.

*Reservoir*, a place for water.

*Retrogradation*, a going backward.

*S*

*Saturated*, filled.

*Sluice*, a flood gate, a drain.

*Subterraneous*, under ground.

*Syzygia*, the conjunction and opposition of a planet with the Sun.

*T*

*Tangent*, a straight line just touching the circumference of a circle.

*Tenſion*, a bending, or ſtretching.
*Tranſit*, a paſſing over, or croſſing.

### *V*

*Valve*, a kind of lid, or cover, letting a fluid paſs one way, but not the other.
*Velocity*, celerity, ſwiftneſs.
*Vertex*, the top of any thing.

### *U*

*Univerſe*, the aſſemblage of Heaven and Earth, or of all created beings.

*The following is*

## THE NEW NOMENCLATURE,

*For moſt or all of the ſubſtances mentioned in this Epitome.*

*Caloric*, heat, fire, igneous fluid, matter of heat.
*Oxygen*, dephlogiſticated air, empyreal air, vital air, baſe of vital air.
*Azote*, phlogiſticated air or gas, mephitis or its baſe.
*Hydrogen*, inflammable air or gas, or the baſe of inflammable air.
*Carbonic acid*, fixed air.
*Sulphuric acid*, acid of vitriol.
*Muriatic acid*, acid of ſalt, ſmoaking ſpirit of ſalt, marine acid.

*Oxygenated muriatic acid*, marine acid more fully ſatu-rated with oxygen, is in the gaſſeous form*.

*Nitrous gas*, two parts of oxygen and one of azote.

*Nitrous acid*, from two to three parts of oxygen to one of azote; this is a red coloured fuming acid.

*Nitric acid*, four parts by weight of oxygen to one of azote; this is clear.

*Nitro muriatic acid*, aqua regia.

*Acetous acid*, vinegar.

*Pruſſic acid*, colouring matter of Pruſſian blue.

* This gas, paſſed through water ſaturated with pot aſh, readily unites with it, and forms an oxygenated muriatic ſalt, which falls to the bottom, and with ſulphur, or various other ſubſtances, deflagrates with great violence.

*FINIS.*

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